TEKNOLOGISK
INSTITUT

# Review of the Current State of RFID


Scandinavian Auto-ID Center

## Contents



Scandinavian Auto-ID Center: http://www.teknologisk.dk/16118

# 1. Introduction

The **overall objective** of this review of the current state of RFID is to get an overview of the RFID-technology and the present examples of applications of RFID-technology in general. The information in this report is fully based on the knowledge and competences of the Scandinavian Auto-ID Centre at the Danish Technological Institute. The references for the statements in this annex are therefore the Danish Technological Institute, 2013.

**R**adio **F**requency **ID**entification (RFID) is an old technology which was already in use for "friend or foe" recognition for anti-aircraft gun shooting in World War 2. Since then RFID has been taken into use for many other purposes, i.e. securing against theft of goods, bridge crossing fees, car keys etc.

The new importance of RFID is connected to certain measures which a group of the world's biggest retail chains and brand suppliers initiated under the name of Global Commerce Initiative at the end of the 1990'es. The interesting part of the vision is that in the same way as it applies to the bar codes, one set of world-wide standards is sought established which can be coded and read by everyone globally.

The above observations underline the fact that many initiatives are taken in the name of conducting good efficient solutions for tracking/tracing in supply chains. And many good solutions are also found today for different industries. However, still no unified solutions have found a global implementation except the one of GS1 barcodes and EPCglobal Standards[1] that is used globally.

# 2. Auto-ID – technologies

## 2.1 Auto-ID systems

Auto-ID is the terminology for technologies for identification of items, objects and products. A number of ID-systems are presently in use. Among the best known and widely spread are,

- Barcodes - GTIN (former EAN/UPC)
- Datamatrix - 2D standard code
- PDF 417
- RFID-tags

**Barcodes – Set of barcodes - GTIN (former EAN/UPC) and SSCC important and widely used -** The main GS1 identifier is the global trade item number or GTIN. This is a number identifying any item traded in the global supply chain that will be priced, ordered or invoiced. The GTIN contains no information. It is used as a key to information held on a database. Each separate product line and packaging level will be assigned a different number or GTIN. A Global Trade Item Number™ may use the EAN/UCC-8, UCC-12, EAN/UCC-13, or EAN/UCC-14 Data Structure. Barcodes are used in most industries and for multiple purposes.

**Data Matrix** - is a symbol that can be etched or printed very small. It can be particularly helpful in marking small parts of small items such as electronic chips for part number and traceability information. The code is a two-dimensional matrix symbol. The encodeable character set of 128 characters conforms to ISO 646 with a user defined extended character set of 256 characters. Error correction may be applied. CCD scanners are used. Data Matrix is an ISO standard.

**PDF417** - is a multi-row, variable-length symbol with high data capacity and error-correction capability. As it is more of a stacked code with very low bars and spaces, some lasers or two-dimensional imaging devices can read it. Every PDF417 symbol contains a minimum of 3 to a maximum of 90 rows. A symbol character consists of seventeen modules arranged into four bars and four spaces. PDF417 is an outstanding portable data file, which can contain substantial information in a relatively small area yet, be easily read to yield full information on a subject or item without access to a database. Uses include medical histories, hazardous material data sheets and full manifest content data to accompany shipments.

**RFID-tags** - Radio-frequency identification (RFID) is an important automatic identification technique with a great potential. RFID-tags are categorised as either active or passive. Many organisations are working in various directions to develop chips and reading capability, which will give accurate data, easily accessible, at prices, which will make the whole system cost effective. A huge research and development project was initiated in 1999 and run by Auto-ID-Centre managed by MIT in Boston, USA and Cambridge University, UK. This closed down in 2003 and the research results transferred to the organisation GS1 (EPCglobal) who has now continued the standardisations related to the retail industry worldwide. Leading international producers of retail brands and supermarkets has been sponsoring the project and is today driving forces in the development.

Below is a comparison on the most frequent used barcodes and RFID:

| Parameter | Barcodes (EAN/UPC) GTIN - SSCC | Data Matrix 2D | PDF417 | RFID-tags Active | RFID-tags Passive |
|---|---|---|---|---|---|
| **Price** | Very low | Relatively low | Relatively low | Very high | High – Decreasing revision 5c tag |
| **Operating Costs** | Low | Low | Medium to Low | High | Relatively high |
| **Printing tolerance** | High | Medium | Medium | N/A | N/A |
| **Reading tolerance** | High | Medium | Medium | Normally none Some frequency problems | Normally none Some frequency problems |
| **ID after damage** | Not readable | Error correction algorithm available | Error correction algorithm available | Protected by build-in solutions – damaged, however unreadable | Protected by build-in solutions – damaged, however unreadable |
| **Reading equipment** | All normal vision reading types | CCD scanners | Laser scanners or 2D imaging devices | Antennas, readers and batteries in tags | Antennas, readers also handheld and mobile terminals |
| **Size Code for ID** | Relatively small | Small | Substantial information in a relatively small area | Label (large) or build into the product | Different sizes and lengths |
| **Variable-Length** | N/A | Yes | Yes | Unlimited information build into tags | UHF EPCglobal GEN2 128/256 bits, others available |
| **Readable/ access to database** | Information is not readable without access to databases | Scanned information without access to a database | Scanned information without access to a database | Information automatically transferred | Access to information direct |
| **Build-in 'intelligence'** | None | None | None | Active Intelligence | Not normally |
| **Overall investments** | Relatively small | Relatively low | Relatively low | Very high presently | Very high presently |
| **Standardisation** | Full standardised | 128 characters conforming to ISO 646 | Industry standards | Different standards presently – future vision on global standard | Industry standards, presently only UHF as global standard |
| **Overall usage** | Relevant in all supply chains especially in FMCG | Used mainly in aircraft/airframe and pharmaceutical manufacturing industry Pilot project see below. | Used widely in automotive industry world-wide | Credit card shaped for use in access applications in many industries. | All shapes for use in different applications. Widely used for anti-theft hard plastic tags in stores. |

**TABLE 1**
COMPARISON ON THE MOST FREQUENT USED BARCODES AND RFID

## 2.2 RFID Basics

Radio frequency identification is a technology that connects objects to Internet or databases, so they can be tracked, and companies can share data about them. The concept is simple: Place a transponder—a microchip with an antenna—on an item and then use a reader—a device with one or more antennas—to read data of the microchip using radio waves. The reader passes the information to a computer, so that the data can be used to create business value.

RFID-technology that can help improve data accuracy by tracking products through supply chains and by identifying products and items/objects at specific points through Automatic Identification (Auto-ID). The technology enables the detection and identification of tagged objects through the data it transmits.

### 2.2.1 Differences in barcode and RFID-technology

RFID is said to have a revolutionizing effect, but some of the benefits can also be achieved already through better use of current barcode systems or by using alternatives like the 2-
D barcode where the barcode technologies presently are cheaper than the RFID-tag.

The main difference is that RFID does not require line of sight as bar-coding does. With RFID, it is possible to read a tag through the packaging or the product itself. The tag can be read independently of the orientation of the tag – it is not necessary to place the tag on a specific side as it is with the barcode label. Furthermore, a significant difference is the amount of labour required – with barcodes a person is required to scan each barcode manually, but with RFID scanning is done by readers and does not require labour.


**IMAGE 1**
RFID TAGS

Tags come in different memory sizes, they can contain a lot of information, and they can be used throughout the supply chain. The data capacity of the RFID-tags enables it to carry more information than the barcode. Tags can stand both heating and cooling to some extent. Standard UHF RFID-Tag can stand temperature up to 80°C and can therefore be used in the production process. Contrary, the barcode is much more fragile, because fluids and rough handling may destroy the readability.

Mass serialization, or the ability to store a unique serial number for every item, is something that cannot be accomplished with traditional barcodes where the number is related to the product category. However, with 2-D barcodes, it is possible to achieve mass serialization, and some people may therefore see this as an alternative to RFID. Still, barcodes cannot offer all the advantages achievable with RFID.

There are many different types of RFID-systems, and installing them and using them to generate data that can be used to cut costs or boost efficiency is challenging. It is important to choose the right type of RFID-system for a particular application. It is also important to work with an experienced systems integrator to make sure the system is installed and configured properly.

The vast majority of RFID-tags or transponders (the tags are often used interchangeably) use a silicon microchip to store a unique serial number and usually some additional information.

There are three types of tags passive, active and semi-passive/semi-active. Passive tags are the most popular type, because of their low cost. They do not have a battery, but instead they get their power from the RFID-reader. The active tags have an on-tag power supply like a battery, which emits a constant signal containing identification information.

Semi-passive/semi-active tags have a battery, but it is only activated when it is in the reader's field.

Passive RFID-systems are the most promising to provide low-cost ubiquitous tagging capability with adequate performance for most supply chain management applications. (See image 2)

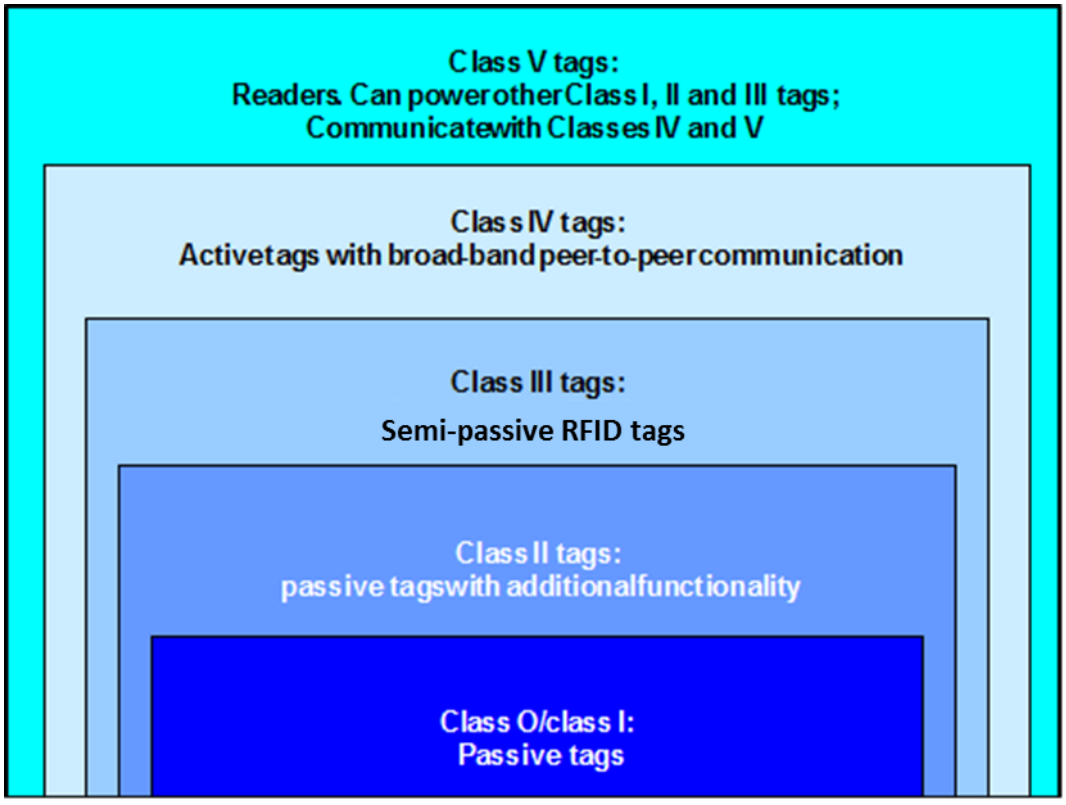


**IMAGE 2**
CLASSIFICATION OF TAGS

### 2.2.2 Passive RFID

Passive RFID-tags have no power source and no transmitter -also called Class O or Class I. They are cheaper than active tags (see below) and require no maintenance, which is why retailers and manufacturers use passive tags in their supply chains. They have a relatively shorter read range than active tags (a few inches to 30 feet, depending on the frequency).
A passive RFID-transponder consists of a microchip attached to an antenna. The transponder can be packaged in many different ways. It can be mounted on a substrate to create a tag, or sandwiched between an adhesive layer and a paper label to create a printable RFID-label, or smart label. Transponders can also be embedded in a plastic card, a key fob, the walls of a plastic container, and special packaging to resist heat, cold or harsh cleaning chemicals. The form factor used depends on the application, but packaging the transponder adds significantly to the cost. Read-only tags are typically passive and are programmed with a unique set of data (usually 32 to 128 bits) that cannot be modified. Passive tags are lighter, have smaller form factors and are less expensive than the more powerful active tags.

Passive tags can operate at low frequency, high frequency and ultra-high frequency. Low-frequency systems generally operate at 124 kHz, 125 kHz or 135 kHz. High-frequency systems use 13.56 MHz. Ultra-high frequency systems (UHF) use a band anywhere from 400 MHz to 960 MHz.The world more or less is divided into three regions with regard to frequencies, 1) Europe and Africa that mainly operates on 866 MHz, 2) North- and South America that operate between 902-928 MHz and 3) Australia and Asia that operates around 915 MHz. Some systems also use 2.45 GHz plus 5.8 GHz and other areas of the radio spectrum.

Radio waves behave differently at each of these frequencies (see illustration in later chapter), which mean the different frequencies are suitable for different applications. They can penetrate walls well, but cannot go through metal. Low-frequency tags are ideal for applications where the tag needs to be read through material or water at close range. Waves in the UHF band are also absorbed by water. The big challenge facing companies using UHF systems is being able to read RFID-tags on cases in the centre of a pallet, or on materials, products and objects made of or containing metal or water.

### 2.2.3 Active RFID

Active tags are used on large assets, such as cargo containers, rail cars and large reusable containers, which need to be tracked over long distances (e.g. in a distribution yard). They usually operate at 433 MHz, 2.45 GHz, or 5.8 GHz, and they typically have a read range of 20 meters to 100 meters (60 feet to 300 feet).

There are two types of active tags: transponders and beacons. Active transponders are woken up when they receive a signal from a reader. These are used in toll payment collection, checkpoint control and other systems. When a car with an active transponder approaches a tollbooth, a reader at the booth sends out a signal that wakes up the transponder on the car windshield. The transponder then broadcasts its unique ID to the reader. Transponders conserve battery life by having the tag broadcast its signal only when it is within range of a reader.

Beacons are used in most real-time locating systems (RTLS), where the precise location of an asset needs to be tracked. In an RTLS, a beacon emits a signal with its

unique identifier at pre-set intervals. The beacon's signal is picked up by at least three reader antennas positioned around the perimeter of the area where assets are being tracked. The position of the asset is defined by triangulation. RTLS are usually used outside, say, in a distribution yard, but automakers use the systems in large manufacturing facilities to track parts bins.

Active tags can be read reliably because they broadcast a signal to the reader. Active systems usually perform better than passive systems in highly metallic environments and rough weather conditions. Because they carry a local power source, active RFID-tags can be expanded and adapted to include additional memory and local processing. They can read, write, and store significant amount of data. They can be attached to sensors to store and communicate data to and from these devices. The prices are rather high compared to passive tags, depending on the amount of memory, the battery life required, whether the tag includes an on-board temperature sensor or other sensors, and the ruggedness required. A thicker, more durable plastic housing will also increase the cost.

### 2.2.4 UHF, low or high frequencies?

All focus is presently on the use of UHF passive systems in the supply chain, rather than low-frequency and high-frequency systems. One reason for this is that some vendors in the UHF market have offered simple, low cost tags. Another important reason is read range. Companies need to be able to read tags from at least 3.3 meters (10 feet) for RFID to be useful in a warehouse. That is because there is no way to read a tag on a pallet going through a dock door from less than 3.3 meters. At closer distances, the reader begins to interfere with the normal operation of forklifts and other equipment. Low-frequency tags can usually be read from within 0.33 meter (12 inches). High frequency tags can be read from 0 – 50 cm, and UHF tags can be read from 1 - 5 meters (3 - 15 feet) or more.

As it can be seen in the RFID-frequency chart (table 2), a number of applications and industries are using different frequencies.

| RFID Frequency Chart | | | | |
|---|---|---|---|---|
| **Frequency<br>RFID Technology** | **Low Frequency<br>125 – 135 kHz** | **High Frequency<br>13.56 MHz** | **Ultra High Frequency<br>400 – 960 MHz** | **Microwave<br>2.45 – 5.8 GHz** |
| **Availability** | > 40 years | > 15 years | US > 10 years,<br>EU > 5 years | > 15 years |
| **Standardisation** | ISO 11784/5<br>ISO 14223, ISO 18000-2 | ISO 14443<br>ISO 15693, ISO 18000-3 | ISO 18000-6,<br>EPCGen1 and2<br>ETSI EN 302 208-1 | ISO 18000-4 |
| **Subsurface (except metal)** | No impact | Low impact | Depends on material | No impact |
| **Fluids** | No impact | Low impact | High impact | High impact |
| **Readability on metal** | Limited | Bad, special tags available | Limited | Good |
| **Bulk reading** | Limited | Up to 50 tags/sec | Up to 150 tags/sec | ?? |
| **Reading distance** | ~ 0 - 30 cm | ~ 0 - 50 cm | US ~ 0 - 800 cm,<br>EU ~ 0 - 500 cm | ~ 0 - 500 meters, active tags |
| **Data transmission rate** | Low | Medium | Fast | Very fast |
| **Interference resistance** | High | High Frequency | Depends on environment | Susceptible to electronic noise |
| **Typical application** | Animal ID, Beer kegs, Car anti-theft, Access control, Personal ID | Track and tracing, Cooling chain control, Person ID, Item level tagging | Supply chain management (SCM), Pallet and container tracking, Trailer tracking in shipyards, Pallet and case tagging | Toll collection, Real time location systems, Long range access control vehicles, Aircraft part maintenance |
| **Industrial sectors** | Farming, Slaughterhouse, Brewery | Airport, Slaughterhouse, Pharmaceutical, Healthcare, Production, SCM product level | Production,<br>SCM on pallet and colli level | Army, Shipping, Airlines and Government |
| **Other** | Oct. 2004 FDA approved a 134 kHz from VeryChip that can be implanted in humans | Smart Card, Rejsekortet | | |
| **Market developers** | | | EPCglobal,<br>US: Wal-Mart, DOD, FDA, EU: Metro, Tesco, Carrefour | Governments, Boeing, Security and safety companies |

**TABLE 2**
RFID FREQUENCY CHART

### 2.2.5 Inductive vs. Propagation Coupling

Read range is determined by many factors, but one of the most important is the method passive tags use to transmit data to the reader. Low- and high-frequency tags use *inductive coupling.* Essentially, a coil in the reader antenna and a coil in the tag antenna form an electromagnetic field. The tag draws power from the field, uses the power to run the circuitry on the chip and then changes the electric load on the antenna. The reader antenna senses the change in the magnetic field and converts these changes into the ones and zeros that computers understand. Because the coil in the tag antenna and the coil in the reader antenna must form a magnetic field, the tag must be fairly close to the reader antenna, which limits the read range of these systems.

Passive UHF systems use *propagation coupling.* A reader antenna emits electromagnetic energy (radio waves). No electromagnetic field is formed. Instead, the tag gathers energy from the reader antenna, and the microchip uses the energy to change the load on the antenna and reflect back an altered signal. This is called backscatter.

UHF tags can communicate ones and zeroes in three different ways. They can increase the amplitude of the wave coming back (amplitude shift keying), shift the wave so it is out of phase (phase shift keying) or change the frequency (frequency shift keying). The reader picks up the signal and converts the altered wave into a one or a zero. That information is then passed on to a computer that converts the binary data into a serial number or the data stored on the tag.

### 2.2.6 Factors that affect performance

It is not necessary to understand the details of the communication methods used, but end users do need to understand the basic characteristics of the different systems and what affects their performance.

Because low- and high-frequency systems use inductive coupling, the size of the reader field is smaller and can be more easily controlled. Ultra-high frequency systems that use propagation coupling are harder to control, because energy is sent over long distances. The waves can bounce off surfaces and reach tags you never expected them to reach; you might even read tags you do not want to read.

Low- and high-frequency systems also work better than UHF systems around metal and water. The radio waves do not bounce off metal and cause false reads. In addition, they are better able to penetrate water; UHF radio waves are absorbed by water. In fact, the problem with reading tags reliably is mainly an issue with UHF systems.

The amount of information stored on a tag depends on whether it is an active or a passive tag, and furthermore the information can be configured in different ways; read-only, write-once-read-many and read-write. Tags also have the ability to monitor measure and record numerous environmental conditions, when combined with a sensing device

### 2.2.7 EPCglobal - presently UHF and HF

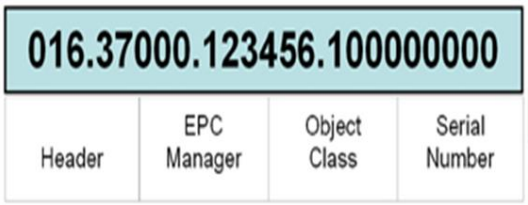


**IMAGE 3**
ILLUSTRATION OF AN EPC[2]

An important issue when dealing with RFID-technology across the supply chain is the level of compatibility. The compatibility refers to the RFID-standards used. Several different standards are developed and applied to the RFID-technology, which can vary between industries and countries. To cope with the degree of compatibility a global technical standard code, EPC standard, has been developed.

Electronic Product Code (EPC) is the next generation of product identification and supports the use of RFID. It is a unique number, which identifies a specific object in motion in the supply chain. Using an EPC makes unique identification of all products possible. EPC is divided into numbers, which can identify the manufacturer and product type, and it uses a serial number to identify unique items.

An EPC number contains:

- Header, which identifies the length, type, structure, version and generation of EPC
- Manager number, which identifies the company or company entity
- Object class, similar to a stock keeping unit or SKU
- Serial number, which is the specific instance of the object class being tagged.

The EPC number is attached to a tag, and by using RFID, EPC can communicate its numbers to a reader, which passes them on to a computer system. When a tag is encoded with EPC it will allow the pallets, cases and, eventually, individual items to be tracked through the supply chain.

EPC Generation 2 is the standard, which is agreed upon. It was developed in a collaboration of leading RFID users and vendors, working through EPCglobal. The full name of what is popularly called EPC Generation 2 is actually EPC Class 1 Generation 2. The specification refers to the second major release of a specification for a tag with write-once memory.[3] The EPC Class Structure describes a tag's basic functionality – for example, whether it has memory or a battery, whereas Generation refers to a tag specification's major release or version number. These specifications provide many options, and for a tag to be fully compliant, it has to offer everything of the above. A reader does not need to have all of these options but can instead be chosen and adjusted to specific requirements and circumstances.

The GS1 EPC network is just one of the many ways in which RFID-data can be shared. The standard requirements for data capturing and forwarding is basically a middleware system, which can handle the data, and a web server that can communicate the data collection.

[2] hhtp://www.epcglobalus.org
[3] ThingMagic (2005)

EPCglobal illustrate the data capturing process like this:

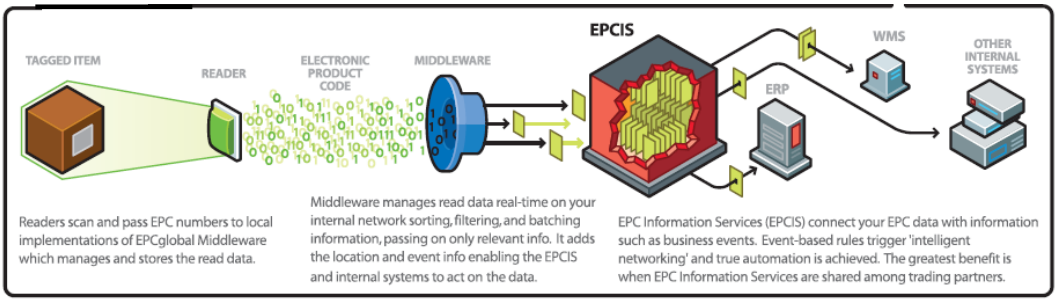


**IMAGE 4**
THE DATA CAPTURING PROCESS

### 2.2.8 Security and Privacy

One of the most important challenges in convincing users to adopt emerging technologies is the protection of data and privacy and this is also an important issue with the RFID-technology. Concerns over data protection are widespread, particularly as sensors and smart tags can be tracked or manipulated unless special security precautions are taken.

When all items in the future come equipped with tags and some of those contain vital data combined with computing and communication capabilities, concepts of data request and data consent risk becoming outdated. There have been some discussions on security breach related to an RFID deployment but so far no actual examples - yet. Businesses and vendors alike acknowledge that security remains a question mark and that it has not so far been highly prioritised compared to the focus on bottom-line results and returns on investment for RFID-enabling the supply chains. With a technology as ubiquitous as radio-frequency identification will be, there is great potential for damage. There is also a risk of damage on barcodes but with RFID, it becomes a freeway. That is why all industries will need to get its security house in order.

A number of security measures already exist, but not all of them are being considered for adoption by the GS1 EPCglobal Network, which provides the infrastructure for sharing RFID-enabled information about products in the supply chain. GS1 EPCglobal maintains the electronic-product-code database, which identifies a manufacturer, product, and version and serial number; provides middleware specifications for data exchange; and administers the Object Name Service for matching an electronic product code to information about the associated item.

The good news is that the industries are paying more attention to the security issue now but much research and developments are still needed in many fields.

Much research on this topic is already taking place and more will come in the very near future.

### 2.2.9 Myths about RFID

*Myth #1: RFID can be used to continuously track people/objects wherever they go – anywhere*

It is true that passive RFID can be used to "track and trace" (track = where is it? trace = where has it been?) products. However, track and trace only works within certain very restrictive conditions. As indicated earlier, an electromagnetic field is needed to power a passive tag to allow it to respond to the reader. This field typically only reaches about 10 to 30 feet. Therefore, unless a tag enters this field, the reader has no idea the tag exists. When a tag enters the field, it can be "tracked" (i.e., the reader knows where the tag is because it is within the read zone) and once it leaves the field, one would know where the tag has been (i.e., traced). Outside of the read zones, however, the tag does not emit a signal nor can a reader locate the tag – a passive tag can only be recognized when it is within the electromagnetic field.

Therefore, continuous tracking of people/objects anywhere in the world would require millions of readers and antennae located in very close proximity to produce the necessary overlapping electromagnetic fields. Even on a smaller scale, to continuously track a box within a 20 acre warehouse would take thousands of readers and antennae – a situation that is simply not economically justified. Instead of continuous tracking, RFID can be used to effectively determine the movement of products through the supply chain by using discrete read points at key areas.

Myth #1, in addition to assuming that a tag can be used as a real-time location device, assumes that people and their possessions will have an RFID-tag. Currently, the emphasis is on tagging pallets, cases and in some industries and single products as they move through the retail supply chain. Overall, RFID can be used for tracking and tracing, but only within defined read zones. Continuous tracking everywhere is not feasible.

*Myth #2: People can drive down the street and read RFID-tags inside your home, thus knowing everything about you and your stuff*

It is possible to read data from an RFID tag without direct line of sight – in fact, this is one of the key advantages of RFID. To read tags inside a home while driving down the street, however, is not likely for several reasons. First, recall that the read range for passive UHF RFID is typically about 10 to 30 feet. Thus, a car or person with an RFID-reader would have to be extremely close to the house to read the RFID-tags. In addition, since the signal can only penetrate about 10 to 30 feet, they would have to encircle your house.

Anything more than about 10 feet from an exterior wall would probably be safely outside the read zone. Second, RFID is affected by water and metal. Not only would the reader have to be very close, but also there could be no RF interference from water or metal. Third, currently, only pallets and cases may be tagged. It is likely that, within the next few years, more item level tagging will occur. If so, the occurrence of tagged products actually being in the home will increase. When RFID tagging becomes ubiquitous at the item level, evil doers may be enticed to attempt to identify products within the home.

In short, current technology simply does not allow one to drive down the street and read everything inside someone else's home.

*Myth #3: RFID-tags contain information about anything and everything, including sensitive personal information*

While this mythical scenario makes for good television, RFID-tags have very limited storage and cannot hold all of the information suggested. Most tags currently have only 96 to 256 bits of information. In the supply chain, RFID-tags contain an electronic product code (EPC) consisting of 96 bits of identifier information. The EPC, much like the barcode, is a family of codes. A common EPC is the serialized global trade identification number (SGTIN). The EPC generally consists of a series of numbers that identify the manufacturer, the product (in some instances, such as the SGTIN), and a unique serial number for the tagged unit (pallet, case or product, for example). With barcodes, companies can identify the product family to which a case belongs (e.g., Paper Towels 2-pk), but they cannot distinguish one case from another. With an SGTIN, each case is uniquely identified. This provides visibility at the case level, rather than the product family level.

Note, however, the absence of the 'mythical' information thought to be contained on an RFID-tag – pictures of the product, names / addresses of key supply chain partners, key dates, etc. It is, however, possible to find much of this information by using the EPC (in this case, the SGTIN) to look up the information in a secure, proprietary database – no different from what is currently done today with barcodes. RFID-tags, in reality, contain only limited information – not vast databases of sensitive, personal information. As used within the supply chain, the EPCs can be used as 'license plates' to uniquely identify a product. Additional information about the product would have to be retrieved from an alternative data source.

*Myth #4: You must have 100% reads at 100% of the read points for RFID to be useful*

Is it possible to read 100% of tagged units at 100% of the read points? Theoretically, yes, practically, no. There are many things that could cause a read to be missed, such as: a person walking in front of a reader as a case passes by could cause the reader to miss the case, and two cases passing through a read point side by side could cause one to be missed, among many others. We refer to the notion of seeing 100% of tagged units at 100% of read points as the "theoretical 100%" read. Although possible, it is unlikely that every tagged unit will be seen at every possible read point.

However, it is highly likely that a tagged unit will be seen at one or more read points. Although retailers expect to see 100% of the tagged units as they pass through the supply chain, they do not expect to see 100% of the units at 100% of the read points. Instead, they expect to see 100% of the tagged pallets as they pass through an appropriate read point (such as inbound doors at a distribution centre) and 100% of the cases after they are removed from the pallet; it is not expected to see 100% of the cases on a pallet. Rather than concentrating on achieving the "theoretical 100%", it is more realistic to ask the questions: (1) was the tagged unit seen somewhere and (2) can a life cycle be constructed from the points at which it was seen? This implicates that you must have a number of reading points at the places you operate.

# 3. RFID in Different Industries

RFID is these days usually associated with the retailing and manufacturing industries, and it must also be admitted that these industries are driving development presently taking into account that major retailers - WalMart, Tesco, Metro etc. - all have set up huge implementation plans for their RFID projects in supply chain on pallets and cases.

Although the financial crisis set back a number of the large-scale implementation plans for some of these companies, still a number of industries have applications running and some have had that for a longer period. The characteristics of these will be described in the following. The descriptions are presented in order of importance and industries with large volumes.

## 3.1 Description of different sectors and applications:

**A. Retail industry - Supply chain management**
Some supermarkets are already today tagging pallets, cases and other returnable items, such as plastic crates used for fresh foods. Tagging the crates gives total asset visibility and allows better management of the asset pool. The ability to write to the tag also allows the addition of information such as the contents of the crate, sell-by date and manufacturer.

Today some of the leading retailers are the front-runners in implementing RFID into worldwide logistics. WalMart has demanded the top suppliers to deliver pallets and boxes with GS1 EPCglobal UHF tags. By the end of year, 2006 there will be 1,000 suppliers, who will deliver pallets and boxes with RFID-tags.

The prices of RFID-tags are still too high to implement widely on item level. Until now, it is only items with high value like Gillette razorblades and fashion items (Gerry Weber), that are tagged, and the tags here are also used as anti-theft protection.

The main reasons for the retailers to implement RFID is cost savings and better information on sales (fashion articles). The large savings will be reduction in manual scanning of pallets and boxes. WalMart has estimated that every manual scanning costs 5 US cent. With 6 billion boxes going through WalMart every year, it is clear that WalMart should be able to save large amounts by eliminating manual scanning.

Other big retailers who are implementing RFID and demanding their suppliers to deliver pallet and boxes with GS1 EPCglobal UHF tags are Tesco, Metro Group, Target, Albertson's, Carrefour and Best Buy.

For the European companies the implementation is not without problems, since the allowed bandwidth in EU is much smaller than in the US. US companies have 24 MHz bandwidth (902-926MHz), while EU companies only are allowed to operate on 2 MHz bandwidth (865.6-867.6MHz). This is giving problems if more readers are operating in the same area.

**Danish implementations (cases and examples)**
The company Computer City has implemented RFID passive UHF tags on individual packaging materials for high value products. The aim was to improve inventory control, streamline stocktaking, ease adjustments of product parameters e.g. sales price, prevent theft etc. The aim was largely met teaming with the software company 2Trace who developed and implemented this system[4].

**B. Food industry[5]**
A major driver for RFID tagging in the food industry is the EU demand for traceability. With RFID-technology, it is much simpler to get traceability in the supply chain. Since 2005, EU legislation has demanded full traceability on food and feedstuff for cattle. The RFID tagging is used on different levels internally in the production line, where 125 KHz or 13.56 MHz tags are used. For example in Slaughterhouses where the flesh hook trees are equipped with RFID-tags, in this way it is not only possible to trace a truckload of animals, it is possible to trace each animal during the slaughtering.

After the products are packed, UHF tags (866-930 MHz) will be used. It is now a demand from many of the big retailers like Wal-Mart, Albertson's, Target, Tesco, Carrefour and Metro, that pallets are tagged with an UHF tag, and shortly it is expected to be a demand that products are also tagged on case level to all the big international retailers.

**Danish implementations (cases and examples)[6]**
The Danish company Danish Crown has developed a track-and-trace solution based on HF-frequency implemented in one of the newest slaughterhouses in Jutland. The solution is an in-house development and implementation.

**C. The US Department of Defense (DoD) RFID Background[7]**
Early experience with Radio Frequency Identification (RFID) began when the Army installed active, data rich RFID-technology at selected sites around the world to track containers through the logistics pipeline and to provide stand-off visibility of container contents. Fixed interrogators installed at key nodes read RFID-tags attached to pallets or containers and provided data to a regional server prior to passing the data to the global asset visibility systems. During the latest operation in Iraq, the use of active, data rich RFID-tags was mandated for all materiel entering into operation.

The use of RFID in the DoD supply chain has the potential to provide real benefits in inventory management, asset visibility, and interoperability in an end-to-end integrated environment. RFID encapsulates the data accuracy advantages inherent in all types of automatic identification technology (AIT). Additionally, RFID is a total non- intrusive methodology for data capture (requires no human intervention), is non- line of sight technology, and is a technology that may possess both read and write options within the same equipment item. RFID addresses a key challenge that has been noted at every node within the DoD supply chain – lack of visibility of item data. As an integral aspect of the overarching suite of AIT capabilities, RFID will become a key technology enabler for the DoD logistics business transformation and will support long-term integration of the Unique Identification (UID) into the DoD end-to-end supply chain. RFID (both active and passive) is required by DoD to:

[4] http://www.2trace.com/fileadmin/PDF_Filer/ShopProtect_case_2xA4.pdf
[5] http://www.giotex.com/en/rfid-tags-slaughterhouse-traceability
[6] Danish Crown - http://www.tekno.dk/pdf/projekter/p04_RFID.pdf
[7] http://www.acq.osd.mil/log/rfid/

- Provide near-real time in-transit visibility for all classes of supplies and materiel
- Provide "in the box" content level detail for all classes of supplies and materiel
- Provide quality, non- intrusive identification and data collection that enables enhanced inventory management
- Provide enhanced item level visibility

**Danish implementations (cases and examples)[8]**
The Danish Army has been one of the first movers implementing RFID. During the first Golf war, it became obvious that the cooperation between the allied countries required 100% control over the individual pieces of goods and equipment.

The leader in command of all the allied countries did not have full control over what deliveries could be expected where and when.

The implementation of RFID has made it possible to track the deliveries from the specific countries and to keep an overview of the supplies. Using RFID-tags with integrated GPS function containers could be tracked. The system is implemented by the Danish Army using in-house resources.

**D. Pharmaceutical industry[9]**
The e-pedigree is a hot topic in the pharmaceutical industry. The origin of pharmaceuticals has to be verified on the item level. There is also need for anti-counterfeiting procedures. The utilization of RFID empowers safe and secure supply and administration of pharmaceuticals. Therefore, the industry is mainly interested in tagging at item level.

At the same time, the FDA (USA) is recommending that all item level prescribed drugs supplied into the US market should be RFID tagged. Originally, the FDA wanted pharmacy products tagged from the beginning of year 2006, but this has not happened. Now FDA commissioner Andrew Von Eschenbach[10] has asked the FDA's Counterfeit Drug Task Force to give an account in a report, with recommendations of how the board should act in order to ensure that RFID is introduced in the medical products supply chain soon.

Another use of RFID in the pharmacy industry is to ensure the cooling chain. It is possible, with an RFID-tag that fits on the bag side of the product label, to see if the cooling chain has been broken.

**Danish implementations (cases and examples)**
Present no examples in Denmark.

**E. Healthcare industry[11]**
In hospitals, RFID-tags can be used to identify patients. On the wristband the patient is wearing, while hospitalized, it is possible to put an RFID-tag. The tag can be used to identify the patient before surgery, to ensure that the right procedures are performed, and to ensure that no allergic reaction occurs, due to wrong medication. In the U.S., as many as 98.000 people are said to die every year due to "mistakes"

[8] the Danish Armed Forces - The Danish Defence Acquisition and Logistics Organization (DALO)
[9] http://www.rfidjournal.com/pharmaceutical
[10] http://www.fda.gov/Drugs/DrugSafety/ucm169918.htm
[11] http://healthcare.gaorfid.com/

in medication or misidentification[12]. In some hospitals in Western Australia[13], active tags are used to identify and track new-borns. After there has been an incidence with a kidnapping of a newborn, one hospital has installed an active RFID-system, which can trace the new-borns and set an alarm if the tag comes too close to the exit.

RFID is also used for asset management in hospitals. With an active tag on the equipment, it is not only possible to see the location of the equipment; it is also possible to see whether the equipment is in use, available or need to be serviced. In emergency situations it is crucial what the staff has the right equipment at hand, and with this tracking system, it is possible to locate equipment wherever available.

One problem with use of RFID in the healthcare industry is that the normal frequencies used for RFID, is also used for some of the equipment in the hospitals. Since it cannot be allowed to interfere with the hospital equipment, it is necessary, to use other frequencies. These can be either low in the UHF band, like 303 MHz[14] or in the microwave band up to 10.6 GHz[15].

**Danish implementations (cases and examples)[16]**
Likewise, in the new Regional Hospitals under development in Denmark RFID will be used to manage medication and asset management on inventory of any kind. Further RFID will be used to locate doctors in the case of an emergency.

**F. Garments - Apparel Industry[17]**
Incorporating RFID-tags into garment labels or even into the garment itself has proven to be a valuable tool for brand owners. A tag inserted at the garment manufacturing plant can identify its source. By using the tag's unique identification number, the garment can be certified as authentic, which enables the identification and control of counterfeits. Grey market imports can be controlled using source identity.

The tags enable inventory visibility throughout the supply chain, reducing shrinkage and out-of-stocks, and the EAS function can reduce in-store theft. Finally, where warranty information is needed for after-sales service, the tag can be written to at the point of sale. One of the resent big scale implementation is done by the German fashion retailers Garry Weber, who has a full implementation in more than 300 stores over Europe.

The US Company American Apparel has a similar set-up.

**Danish implementations (cases and examples)**
No cases implemented in Danish companies yet.

[12] http://www.iom.edu/~/media/Files/Report%20Files/1999/To-Err-is-Human/To%20Err%20is%20Human%201999%20%20report%20brief.pdf
[13] http://www.pcworld.idg.com.au/index.php/id;484455565;fp;2;fpid;1
[14] http://www.rfidjournal.com/article/view/920
[15] http://www.rfidjournal.com/article/view/1088
[16] http://www.dnu.rm.dk/bygherre/it/logistik+og+it/sporbarhed+og+emne-id
[17] http://www.rfidjournal.com/articles/view?3788

## G. Parcel and post[18]

RFID is being used today in the postal environment to enable improved item tracking during the sorting and delivery processes and for quality control plus tracking of letters. RFID does not require a line of sight for information transfer, so it allows postal items to be routed without concerns over item orientation. Multiple items can be read as they pass through the reading field.

### Danish implementations (cases and examples) [19].

For several years, Post DK has used RFID for performance measurements. Tagged letters are sent and subsequently registered at strategic points to monitor delivery time. The parcel containers used by Post DK are also RFID tagged to maintain efficiency and overview.

In 2006, Post DK RFID tagged post containers. More than 34.000 were tagged. One of the consequences of this was that 10.000 containers "were found" and investment in new containers for 4 mill EURO could be prevented. The Danish company Lyngsoe Systems A/S implemented these two Danish applications

Post DK established in 2010 a countrywide net of active RFID-tags mounted in every mailbox and antennas in the postal truck. Thousands of tags and readers have been installed. Further, the postal trucks were equipped with GPS, which offers information on active driving time and distance driven. The system also provides data of big value for logistics planning purpose, which overall makes Post DK more efficient. The Danish Company Commotive A/S implemented the system.

With the infrastructure in place, Post DK can offer external partners to track their stolen assets like vehicles, machines, trailers etc. Commotive A/S offers the RFID active tag "Diims" which makes tracing possible via Post DK´s reader network.

## H. Container tracing[20]

The transportation of a container does not only involve just one company. Containerized transport involves a large number of handoffs and complex interactions between the manufacturer, shipping line, ports, marine vessels, dray operator and other members in the transport chain.

Inter-modal transport is even more complex, as a container moves between rail, sea and land. Furthermore, a container often travels over international lines with different laws regarding transport liability. RFID-technology is here used for electronic container tracing that allows for audit trail, so end-users and shippers can know the exact point where the supply chain went awry.

Two key areas where the feature plays a significant role are to ensure the security of the container, and to streamline the supply chain. In addition, the greatest factors in the security area are in lost prevention and terrorism reduction. The two security issues can be addressed simultaneously with RFID electronic cargo seals and improved end-to-end standard security procedures.

[18] http://www.rfidjournal.com/articles/view?4270
[19] http://www.rfidjournal.com/articles/view?9257
[20] http://www-05.ibm.com/de/automotive/downloads/rfid-container-management.pdf

**Danish implementations (cases and examples)** [21]

In the area of container tracking, Container Centralen has one of the largest Danish implementations. Container Centralen collects flowers and plants from farmers and growers. Container Centralen has 3.5 million wheeled containers in Europe equipped with RFID-tags, so that they can be read at each transfer. Thus, it is possible for the gardeners to track where their products are transported to and how far they have come. All wheeled containers are rented out to gardeners and a good deal of repair is related to the handling. A number of pirate containers have been present in the system. This was reduced when the RFID-tag mounted on the original containers are equipped with a code that cannot be read by equipment which does not have Container Centralen software installed.

Container Centralen, teamed with IBM to develop and implement the system to eliminate counterfeit containers from the supply chain with a secure RFID tagging system.

In addition, the small company Munnin Spot Technology (previously Moving World Technology) has developed an active RFID tag with integrated GPS, temperature- and other sensors, to monitor the location and other characteristics of the asset as required.

**I. Airport**

Baggage tagging; Many airlines have run RFID trials over the past few years to prove the efficiency of the systems employed in the air transport environment. Tests have shown first-read rates of over 99% with RF tags compared to less than 90% for bar code-only tags.

In some of the biggest airports like Las Vegas[22], RFID UHF tags are now used to track the luggage. The luggage is via the tags send through a central explosive-detection system, and afterwards routed to the appropriate airplane. In case suspected contents are found, the luggage is send to another security-screening station. With the old barcode system 15-30% of the barcodes were not read. That entire luggage used to be hand scanned which was very time consuming.

With the RFID-tags, the reading accuracy rate has been 99.5%, which ensure faster handling and less lost luggage. Among other airports that have started using RFID for the luggage handling is: Brussels's Zaventem, Stockholm's Arlanda, Denver International Airport, San Francisco International Airport and Hong Kong International Airport[23].

The U.S has also started to issue RFID passports[24]. The RFID chip will be shielded, so it will not be possible to scan the passport as long as the passport is not open. The passport will store all the data normally written in the passport, together with a photo for biometrical analyses of the passport holder.

[21] http://www-01.ibm.com/software/success/cssdb.nsf/CS/SSAO-8FNHCE?OpenDocument&
[22] http://www.rfidjournal.com/article/articleprint/1949/-1/1
[23] http://www.rfidjournal.com/article/articleview/981/1/1/
[24] http://travel.state.gov/passport/passport_2498.html

**Danish implementations (cases and examples)[25]**

Different pilot tests with RFID have been carried out at airports in Denmark. Copenhagen Airport has since 2008 tested the RFID-technology to keep more track of the passengers. A RFID tag was "matched" to the passenger's cell phone, if they accepted it, and the passenger could then be guided to the gate, so that they arrived on time.

At Aalborg Airport they mount a RFID-tag in the luggage strip in order to avoid errors in the handling of suitcases. With the implementation of RFID Aalborg has achieved an optimization which has resulted in increased luggage handling capacity. Thus an expansion of the airport could be put off. At the same time the implementation of RFID can help if passengers do not show up at the gate/plane. Previously all luggage had to be checked. With RFID the suitcases are scanned and in that way quickly found. The Danish system integrator Lyngsoe Systems, who has also been involved in many of the international airport installations, has developed the system.

## K. Cars and Vehicles

In the car making industry, RFID is used for different purposes. For anti-theft systems[26], where low frequency tags are implanted in the car key, making sure, that only the key with the right tag can start the car. And for the assembly line to ensure that the right spare parts are being used.

For toll-collection[27], RFID-tags are used in fast lanes, where the car has an active UHF RFID-tag placed in the front windshield, and when the car passes the tollbooth, payment are automatically made.

In France, the brobizz type of RFID is used for road taxation, eliminating waiting/stop time for road users and minimizing administration of road taxes.

The trucking manufacturing company Volvo is also working with RFID for asset management[28]. This is giving the opportunity to have better control of the components flow in the production. Volvo is also running trials with UHF tags on fuel cells.


**IMAGE 5**
A CAR PASSING THE TOLL BOOTH AT SYDNEY HARBOUR BRIDGE

**Danish implementations (cases and examples)[29]**

In Denmark RFID-tags have for years also been used in the Danish Brobizz. The Great Belt, The Sound, Scandlines and Mols-Linien are cooperating, so that the same brobizz can be used on several bridges and crossings.

[25] http://www.lyngsoesystems.com/airport/rfid_baggage.asp
[26] http://rfid.emmicroelectronic.com/webfiles/Product/RFID/AN/Wireless.pdf
[27] www.eleceng.adelaide.edu.au/personal/peter/peter/GENERAL/RFIDPix.doc
[28] http://www.elektroniktidningen.se/index.php?option=com_content&task=view&id=18114&Itemid=87 (Swedish)
[29] http://www.storebaelt.dk/english

## L. Libraries and media management

RFID is used in many libraries to automate the issue and return of books, videos and CDs and to give real-time visibility for library inventory. Until recently, books and CDs have been identified using barcoded labels, each of which had to be read individually with a bar code reader. Inventory control and reconciliation has been a time-consuming operation.

With RFID, books and CDs can be checked in and out automatically and inventory control can be automated using scanners on shelves or with their hand-held equipment. The result is a reduction in the need for personnel and a much higher degree of accuracy in inventory management.

### Danish implementations (cases and examples)[30]

RFID tagging has been implemented in most Danish Libraries. By using RFID tagging, the citizens are able to handle all issuing and returning of books by themselves. Hereby time is released to the librarian, which can be used on service assignments. Tag Vision and Lyngsoe has been the provider of several of these systems in Denmark.

## M. Animal detection[31]

With increased concern about food safety and the spread of livestock diseases, countries are mandating the identification of individual animals. The electronic tracking of animals, greatly simplifies this process. On the farm, information can be logged for each animal from growth rates and feeding to health stats and breeding. On the move, accurate information is gathered, without handling the animal, to ensure traceability. The scheme is to ensure that meat, and its history, can be traced back to the individual animal. RFID-tags are being used to identify millions of livestock animals around the world. With the RFID-tag in an ear tag farm management and data collection can be automated for breeding practices as well as quality and traceability.

RFID improves the tracking of animals both large and small so they can be more quickly located and maintained. Animal tracking is the largest implementation of asset tracking, production control, and retail logistics in the world. From livestock management systems to scientific research, RFID can help farmers, ranchers, conservationists, etc. to locate and evaluate their domesticated and non-domesticated assets. There are companies and national schemes utilizing RFID-systems products to identify and track cattle, sheep and other livestock. By placing a tag on the animal, details can be gathered concerning health information, animal movement, or market eligibility. Still other companies and foundations are using RFID-tags to track wildlife and fish in order to better understand migration and/or spawning patterns. These patterns can then be analysed in a database to learn more about the habits of the wildlife all around us.

The International Standard for Radio Frequency Identification of Animals ISO 11784 /11785 based on 134.2 kHz technology is most frequent used.

[30] http://www.tagvision.dk/

[31] Texas Instruments - http://www.ti.com

**Danish implementations (cases and examples)**
Denmark has also implemented ”tagging” of cows/calves. From 2010[32], each newborn livestock must have a RFID-tag in the ear, which states owner and identity[33].

The Pigtracker UHF RFID based system increases the farmer’s productivity by keeping track of pigs and controlling different aspects of the upbringing of the individual pigs e.g. feeding, medication, location etc. The Danish company Prosign supplies the system[34].

**N. Asset Management – different types of assets**
TrenStar owns, manages and tracks millions of beer kegs in the UK. They own more than 60 percent - and counting - of the total number of kegs in the UK, where customers with long-term contracts with the company benefit from the mobile asset management solution. Individual brewers can take advantage of a complete solution that includes asset acquisition, asset management, maintenance, logistics services and RFID-technology. Carlsberg, Coors U.K. and Scottish & Newcastle are now seeing the results of TrenStar’s mobile asset management solution. Between the three, more than 3.5 million kegs have been fitted with RFID-tags and are now tracked at 11 different locations. TrenStar is currently responsible for 2.6 million RFID scans per month, which is just over

**Danish implementations (cases and examples)**
Berendsen Textil Service rent out work clothes to companies to be used by their employees – specific clothing to specific persons. Berendsen does the laundry too and manages the distribution, collection, wash, and redistribution back to the individual person locker by use of RFID-technology. Each individual piece of clothes is RFID tagged.

The furniture producer Fritz Hansen uses an active RFID-tag in combination with GSM implanted in their furniture and thereby prevent theft or at least identify stolen goods. An Active tag with battery as energy source emits a signal regularly e.g. once per day that is read by the GSM posts situated all over the country and the position can be defined even if placed in house or in areas where GPS will not work. Munnin Spot Technology (previously Moving World Technology) has implemented this solution[35].

[36]Danfoss Drives uses four fully automatic print-and-apply machines to write and attach a paper-thin UHF RFID Gen 2 tag embedded in a label on every product as Danfoss Drives produce. The label is hidden behind a thick layer of plastic, but the RFID-label of the products, makes it possible to read the content even if the bar code label cannot be seen. Previously a barcode was used but mis-readings were numerous and a shift to RFID has shown to be a success and has raised the quality level of the company’s internal processes. The company PCSYS implemented the system.

[32] https://www.retsinformation.dk/Forms/R0710.aspx?id=137043
[33] https://www.landbrugsinfo.dk/kvaeg/registrering-og-maerkning/Sider/Elektroniske-oeremaerker-banker-paa.aspx
[34] http://www.prosign.dk/forside/alle-cases/pigtracker/
[35] http://www.tekno.dk/pdf/projekter/p04_RFID.pdf
[36] http://www.pcsys.eu/BarcodesRFID/References

Icopal[37] has had PCSYS to deliver an RFID solution where roofing felt is labelled with RFID-tags during the production, while the asphalt is still hot and liquid. Subsequently the RFID-tag is used for tracking the items in the store, theft proofing on construction sites and for quality assurance when the roofing felt has been on the roofs of buildings for many years.

**O. Energy Sector[38]**

Improving asset tracking and inventory management is a major driver of RFID in the energy sector. Managing assets in remote regions is particularly challenging. It is very costly to send vessels to offshore oilrigs, so they need to make sure they are taking everything that needs to leave—that is a very laborious process to try to do manually. RFID can speed up this process considerably and simultaneously provide data that are more reliable.

Cameron, a provider of flow equipment products, systems and services to worldwide oil, gas and process industries, has been RFID-tagging valves and rental equipment for U.S. and Canadian hydraulic fracturing companies, to improve asset tracking and inventory management.

The company links the unique serial number on each passive UHF EPC Gen 2 tag to information about the part stored in its database. The RFID-solution provides more accurate data and visibility into what equipment has been shipped to and returned from customers, and identifies items that are being repaired. Further the company can speed up billing and bring greater efficiency to other business processes, including turning around customer order cycle time. Knowing the status of equipment is key to providing better service.

Oil and gas companies are also using RFID to improve drilling and maintenance operations, thanks to technology advances that make it possible to read tags on metal and in harsh environments. However, most RFID deployments in the energy sector are closed-loop applications. The holy grail is to have RFID used across the supply chain—from the manufacturing site, where it can be attached to equipment being produced, to the wellhead, where it can be used in operations,

To monitor valves and other equipment used in fracking, Cameron needed metal-friendly tags that could survive stress and harsh environments, so they would be readable when the assets were returned to its facilities. There are all sorts of harsh chemicals that tags are exposed to, so the tags and attachment mechanisms have to be durable on multiple fronts. UHF tag technology has advanced so far recently and become so much more robust and have a high survival rate with companies like Xerafy, Omni-ID and Confidex.

The advancements in UHF technology can also facilitate oil and gas drilling operations and other processes that take place in the field, Workers can read RFID-tagged pipes to ensure the right pipes are going into a hole in the right sequence, for example, or that a pipe has been inspected following its use in multiple drilling cycles.

[37] http://www.icopal.dk/Produkter/Tagpap/500_serien/Minirillesystem.aspx
[38] http://www.rfidjournal.com/articles/view?11526

RFID-solution from Trac ID Systems at offshore oil wells is used to monitor the lifespan of drill pipes. Each time a pipe is lowered into and then raised out of the well, its tag ID number, along with the time and date, are automatically recorded. Tracking the pipes with fixed and handheld readers provides more accurate data than recording the information manually, and it also minimizes the time the rig crew must spend on the main deck, where they are exposed to various hazards.

**Danish implementations (cases and examples)**

[39]Veriloc cooperates with the water and heating utility companies like Hovedstadens Forsyningsselskab (HOFOR) and Vestforbrænding A/S are using RFID in different applications for asset management, maintenance and efficiency.

An RFID-tag is mounted on all components, either during production or at a central warehouse. When ordering online the customer will receive an order number and a unique item number on the ordered components.

The customer receives an electronic delivery note, in which each component with its own unique RFID number plate and the technical specifications is coupled to the order.

When the components arrive at the construction site, the handheld RFID-reader will scan all the RFID number plates easily, and the delivery notes are automatically updated via the construction manager's smartphone. The construction manager does not have to press any key on his smartphone. The signal goes automatically from the RFID-reader to the smartphone and continues to the Veriloc system. In case of an error there will be given a warning to the construction manager and the vendor. If it is the correct components, they can be put in place ready for welding. The individual components are recorded with a GPS position.

Subsequently, they can be tracked very precisely in relation to the position and depth. The Veriloc system is adapted to the special conditions of each customer in close cooperation.

RFID-tags, can be supplied to measure the temperature inside the pipe. In the near future it is expected that RFID-equipment can also measure air pressure and humidity in the pipe. In this way the installation can be monitored constantly providing exact information about where and when to do maintenance of defect or old pipes and components. With RFID-technology the maintenance budget can be controlled much tighter and provide more reliable deliveries of water and energy supplies.

**P. Waste Management**

With costs rising at all points in the waste management process, RFID-technology can enable those involved in the industry to improve the efficiency of their waste operations. In the following are given a few examples of the use of the RFID-technology in relation to handling of waste.

Collection of municipal waste in Kristiansand, Norway (40 - When Avfall Sør Husholdning AS (Southern Household Waste Co.), a Norwegian waste-management firm, bills the 45,000 households it serves in the city of Kristiansand, the company

[39] http://verilocautomation.com/index.php?option=com_content&view=article&id=15&Itemid=2&lang=en

[40] Source: AMCS Group, UK – www.amcsgroup.com/uk/)

utilizes RFID-based data to track the quantity and type of refuse collected.The tag is attached or embedded to/in the waste bin of each household. An RFID-reader and antenna is integrated into the waste collection vehicle and connected to a host controller, which reads the tag's unique serial number as the waste bin is emptied. This unique number can be linked with a date/time stamp, type of container, weight of the container and household information. That information can be sent directly to a server using wireless connectivity, stored in the reader or on the vehicle's on board host controller and transferred later to a central waste management system.

In communities with these, pay-as-you-throw (PAYT) programs (also known as unit pricing or variable-rate pricing), households are charged for the collection of municipal solid waste based on the amount they throw away. This creates a direct economic incentive for the household to sort and separate more and to generate less waste. Traditionally, households pay for waste collection through a fixed fee regardless of how much or how little waste the household generates.

In order to protect the tag from the environmental harsh conditions that exists in the waste handling the tag is placed in a rugged plastic housing or embedded in the waste bin to protect it.

*Recycling of printers in Brazil* - HewlettPackard in Brazil[41] (HP-Brazil) started in 2007 to tag their printers with passive UHF RFID tags with the GS1 EPC standard with the purpose of tracking printers through production and distribution. The goal has been to use the tag information to manage the end-of-life products. The EPC and serial numbers on each tag link to a database with a large amount of information about each printer, including its recyclable materials e.g. different types of plastics, metals etc.

The RFID-based recycling program started in July 2011. The printers are collected from drop-off centres and sent to a recycling facility where they are disassembled. Before entering the disassembly line, the tags EPC codes are scanned and data transmitted to HP's business intelligence software that iis integrated into a manufacturing product database, which contains information about each tagged printer.

Based on the tag data HP-Brazil can calculate the amount of printers sold and returned, amount of recyclable materials, balance out amount of material to be purchased from the market vs. use of own recycled materials etc. The recycling facility takes control over materials HP does not need for reinsertion into new printer products. Roughly, 40 % of materials in HP´s new products are recycled.

Over time multiple reuses of recycled materials can present a challenge as engineering properties of the recycled material changes/deteriorates. But the EPC data on the tag will identify which plastics can be recycled and which will need to undergo other forms of treatment. The experience from this project is that most tags are still functioning after 5-6 years.

[41] www.rfidjournal.com/purchase-access?type=Article&id=9754&r=%2Farticles%2Fview%3F9754

**Danish implementations (cases and examples)[42]**
The Danish company Dansk Retursystem A/S has a pilot project running on returning empty bottles and cans. Citizens can now return their disposable bottles and cans in a RFID tagged plastic bag at a deposit station placed at a municipal collection point and get the deposit transferred directly to their bank account.

When the bag is filled with approximately 100 bottles or cans, it is sealed and handed in at the deposit station. The RFID tag on the sack links the bag-information with the credit card or charge card used in the machine at the deposit station. This ensures the deposit to be credited to the correct bank account.

Dansk Retursystem A/S collects the bag at the deposit station and counts the empty bottles and cans. Citizens can follow their bag from delivery until the refund is credited to the bank account on a website .

The concept of deposit stations is developed as part of the further development of the Danish deposit and return system. The goal is to make it even more efficient and citizen-friendly to return empty packaging, thereby motivating people to return even more empty packages for the benefit of the environment and recycling of resources. Dansk Retursystem A/S has developed the physical layout and different sub suppliers[43] have delivered the software and RFID tags.

**Q. Other areas and examples**
**Personnel Safety:** The oil companies BP, ConocoPhilips, Chevron, Exxon and Shell are using RFID in major projects for personnel safety. Staff members are tracked and monitored so in an emergency situation it can be determined which employee have reported to their assigned mustering stations as well as the locations of those who have not, and it can issue alerts in the right areas if a rescue is in order. They can proactively reduce the risk of an incident for example triggering alarms when non-authorized contractors enter restricted work zones or notifying managers if noncertified operators get near heavy machinery or restricted areas. RFID can provide more exact information to be used by management for public messages in the case of an emergency. Most personnel safety solutions consist of a combination of real-time location systems based on ultra-wideband, ZigBee or Wi-Fi active RFID and GPS capabilities. Some have also a panic button and sensors that could detect a fall to the ground or off a harness.[44]

**Safety Inspection:** RFID can automate safety inspections. Omni-ID, is working with a customer on an RFID automated inspection program on ships.

A strict inspection program on each ship requires not only ensuring the presence of fire extinguishers but also stress-testing on-ship components and parts of the ship itself, such as a doorway to ensure its hinges and locks work properly. With durable passive UHF tags attached to the appropriate locations and components on the ship, personnel need only ping the tag with a handheld reader to access complete instructions for what testing to do at each location. Moreover, once they complete the tests, there's a full electronic record to show compliance with safety.[45]

[42] http://pantstation.danskretursystem.dk/
[43] Suppliers: Antenna - Prosign RFID, Struer, Denmark, Labels and tags - RF-Labeltech, Randers, Denmark, Software – Grontmiij, Glostrup, Denmark
[44] https://www.rfidjournal.com/purchase-access?type=Article&id=10615&r=%2Farticles%2Fview%3F10615%2F3
[45] http://www.rfidjournal.com/articles/view?9322

**Sporting event; Vasaloppet:** The first Sunday of March there is a major ski contest held in Dalarna, Sweden. The name of the race is "Vasaloppet" (the Vasa race) and it is the biggest ski event in the world. 14,000 skiers participate in the main event and including all the side events during the week the number increases to 40,000 skiers. In order to keep track of all the skiers and their results a RFID-system, from Championship, Netherlands, (in cooperation with IBM) is used. Participants are equipped with a RFID-tag, which is mounted on the leg. In total each skier pass nine "choke points", including start and finish, during the 90 kilometres of skiing. Each time a "choke point" is passed the transponder communicates with the reader and sends its information. The information is publicized on the internet and it is even possible to access the information via cell phones in form of text messages.[46]

**Danish implementations (cases and examples)**

**Sporting event Eremitageløbet:** Every October since 1969 the 13.3 km. Eremitageløb (Eremitage race) is run in Dyrehaven in the outskirts of Copenhagen with 20.000 participants. Timekeeping is performed using high frequency RFID-system. The RFID passive tag is placed at the rear side of the participants' start number, which the participant must carry, visible on his/her breast. The reading is performed at start, at specific points during the tour and until the finish. At start and finish, a back-up system ensures 100% registration. Elapsed times including participant specifics can be communicated to the participants via SMS and to the management of the race during the run. RFID-readers placed near the goal sends information to the speaker, which allows him to announce details about participants approaching the goal. The tags need not to be returned minimizing administration of the system.[47]

**Lalandia water world**: Lalandia in Billund has RFID-tags equipped in admission cards. The card is actually a bracelet, which is worn throughout the vacation. In connection with the water world are also holiday cottages. The key to these holiday cottages is also the same RFID bracelet. The bracelet also functions as admission card and means of payment in the water world and adjoining shops/cafés/ restaurants. In that way children on vacation with their parents, can be given a budget each day, which they can use to buy products[48] IBM is the solution provider.

**Grundfos LIFELINK**[49:] Grundfos LIFELINK offers an innovative turn-key solution for sustainable water supply in both community based water projects and for public or private water service providers. Technically, the Grundfos LIFELINK system consists of a submersible pump, which is submersed into a borehole with clean drinking water. The pump is operated by solar panels, which deliver inexpensive, reliable and environmentally friendly energy. The users tap the water from the automatic water dispenser using a RFID smart card with water credit.

The payment system is one of the key factors of sustainability as it ensures that the means for service and maintenance are paid into a closed bank account. Via an interface using the successful mobile banking system M-PESA, the community members can use a mobile phone to transfer credit to the water key, which they use to draw water by the tapping station. Veriloc has supplied RFID smart cards and readers.

[46] http://www.mediatecgroup.com/news/2013/cheerleading-at-vasaloppet
[47] http://www.elob.dk/Forside-1.aspx
[48] http://www-304.ibm.com/businesscenter/cpe/download0/175182/Lalandia_refcase.pdf
[49] http://www.grundfoslifelink.com/

### 3.1.1 Expected benefits for companies

To give a brief exemplification of the expected benefits of RFID, different companies, consultants and articles describe a number of benefits derived from initiating RFID solutions. The presentation gives an indication of what can be achieved with RFID.

| Expected Benefits | |
|---|---|
| • Labour efficiency/savings<br>• Out-Of-Stock Management<br>• Inventory Management<br>• Receiving shipping accuracy<br>• Reduced claims<br>• Reduced not saleable items<br>• Reduced diversion<br>• Product recall management<br>• Better visibility<br>• Better fulfilments<br>• Product integrity<br>• Increasing capacity utilization and yield<br>• Reducing cycle time<br>• Increasing labour productivity<br>• Improving product quality | • Ensuring timely preventative maintenance<br>• Reducing product obsolescence costs<br>• Tracking and managing spare parts inventory<br>• Facilitating statistical process control<br>• Enabling lot/batch track and trace<br>• Ensuring worker safety<br>• Reducing returns and warranty claims<br>• Reducing scrap, waste and obsolescence<br>• Better planning and forecasting<br>• Better processes in VMI systems related to reordering<br>• Traceability and safety of products for counterfeiting and maintaining copyrights<br>• Better asset management and handling of returnable assets |

**TABLE 4**
EXPECTED BENEFITS SOURCE: a.t. Kearney (2004) & Chappell and Ginsburg et al (2003) & DTI, auto-id centre (2012)

In table 3 below is an overview of Danish actors within the RFID-technology

## 3.2 Danish Suppliers of RFID-Solutions

| Company | Address/ e-mail/homepage | Services | Cases |
|---|---|---|---|
| **RF LabelTech A/S Danish** | Nyholmsvej 4<br>8930 Randers NØ,<br>rfid@rf-labeltech.dk<br>www.rf-labeltech.dk | Special designed RFID-tags | Tag producer and supplier |
| **Lyngsoe Systems A/S Danish** | Lyngsø Allé 3<br>9600 Aars<br>info@lyngsoesystems.com<br>www.lyngsoesystems.com | Software development and systems integration of logistics solutions. Systems design, installation maintaining control and track-and-trace systems.<br>WMS and WCS.<br>Automaton of sorting and distribution centers.<br>Warehouse logistics and traceability | • Postal solutions Post DK,<br>• Airport solutions in Aalborg, Hong Kong, Milan Malpensa,<br>• and many more cases<br>• Library solutions- Kolding, Hamburg and at least 8 others<br>• Supply Chain solutions<br>• Skanlog, Oticon and several others. |
| **TagVision Danish** | Tranevang 2,<br>3450 Allerød,<br>info@tagvision.dk<br>www.tagvision.dk | Specialized in RFID-solutions for libraries.<br>Specialized in HF | More than 50 references from libraries in Denmark, Sweden, Norway, Netherlands, Belgium and England |
| **Commotive A/S Danish** | Rebild Skovhusevej 17,<br>9520 Skørping,<br>info@commotive.com<br>commotive.com | Designs unique solutions for the optimization of the postal processes and on top of this to further develop its patented tracking platform. | Post DK |
| **Munnin Spot Technology ApS Danish** | Vitus Bering Innovation Park<br>Chr. M. Østergaards Vej 4a,<br>8700 Horsens,<br>rna@munninspot.com<br>www.muninspot.com | Concept development – tracking and tracing, theft prevention | Fritz Hansen - furniture |
| **2Trace Danish** | Høffdingsvej 20,<br>2500 Valby<br>info@2trace.com<br>www.2trace.com | Software, reading and integration in ERP systems<br>Has developed a software that can detect whether a product is entering or leaving a room, using the strength of antenna signal | Computer City - inventory management, shop management and theft prevention<br>Berendsen Textile - tack and trace, inventory management |
| **Veriloc Automations ApS Previously (Beta Technic) Danish** | Veriloc Automation ApS<br>Herlufsholmvej 37<br>2720 Vanløse,<br>info@veriloc.dk<br>verilocautomation.com | Systems for asset management for water and heating utility companies. Primarily UHF but also HF and LF | Hovedstadens forsyningsselskab (HOFOR),<br>Vestforbrænding,<br>Grundfos LIFELINK |

| Company | Address/<br>e-mail/homepage | Services | Cases |
|---|---|---|---|
| **Prosign ApS**<br>**Danish** | Fælledvej 17,<br>7600 Struer<br>info@businessparkstruer.dk<br>www.prosign.dk | Complete RFID-solutions including development, specification, application, installation integration and service. Supply of hardware, software and training | Pigtracker, Færch Plast, Post DK |
| **IBM Danmark ApS** | Nymøllevej 91<br>2800 Kgs Lyngby<br>www.ibm.com/dk/da/ | Systems in a wide range of applications | Container Centralen – container tracking<br>Many international cases |
| **Siemens A/S Industry** | Borupvang 3<br>2750Ballerup,<br>ind-<br>ekspedition.dk@siemens.com<br>www.siemens.com/ | Tags, Readers, Systems integrations | Several cases within several industries, mainly production |
| **Allflex,**<br>**Tracecompany,**<br>**TRU-TEST Scandinavia A/S,**<br>**Destron Fearing,** | | Systems for animal identification – LF frequency | Tagging of cows/calves |
| **PCSYS**<br>**Danish** | Brøndby<br>Midtager 29<br>2605 Brøndby<br>info@pcsys.dk<br>www.pcsys.dk/ | Provides complete RFID-solutions including consultancy, total supply of hardware, software, installation, integration with ERP, WMS and shop floor systems within<br>• Inventory management,<br>• Preventive maintenance | Danfoss Drives – quality and production management<br>Icopal – inventory management , theft prevention |
| **ESCON Warehouse Systems** | Finlandsgade 33<br>8200 Århus N<br>info@escon.dk<br>www.escon.dk | Provides complete logistics solutions for warehouse and supply chain management and includes all the necessary software and hardware components incl. RFID. VMS systems. | Pigernes Verden – textile shop – inventory management, shop management – theft prevention |
| **Intermec Technologies A/S** | Gydevang 31-33<br>3450 Allerød<br>www.intermec.dk/ | Covers data collection, mobile computer solutions, RFID, wireless and non-wireless conductivity or printer and media solutions.<br>• Stationary reader with built-in antennas.<br>• Handheld readers<br>• Readers specifically designed for mounting on trucks. | Sub supplier of hardware, software to a number of the above cases |

**TABLE 3**
DANISH SUPPLIERS OF RFID-TECHNOLOGY

### 3.2.1 Internet of Things

The vision "the Internet of Things" combines internet, ERP-systems in companies, mobile units so that you more or less can stay connected all the time or at least have the ability if it is convenient for people or companies. Here the RFID-technology is one important element to combine or stay connected and many of the above mentioned solutions in different industries are one step in fulfilling that vision.

The Internet of Things refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure. The term Internet of Things was first used by Adam Baumgarten in 1999. The concept of the Internet of Things first became popular through the Auto-ID Center and related market analysts publications. RFID is often seen as a prerequisite for the Internet of Things. If all objects and people in daily life were equipped with radio tags, they could be identified and inventoried by computers. However, unique identification of things may be achieved through other means such as barcodes or 2D-codes as well.

Equipping all objects in the world with minuscule identifying devices could be transformative of daily life. For instance, business may no longer run out of stock or generate waste products, as involved parties would know which products are required and consumed. One's ability to interact with objects could be altered remotely based on immediate or present needs, in accordance with existing end-user agreements.

Although the Internet of Things is a relatively new vision, its enabling technologies have been around for some time, developed in relative isolation from each other. RFID was invented in the middle of the last century and materials using nanotechnology have been on the market for over a decade. The impact of a combination of such technologies cannot be underestimated which we revert to in a later chapter on RFID in future waste management.

The Internet of Things vision takes a look at the next step in “always on” communications, in which technologies like RFID, mobile and smart computing promise a world of networked and interconnected devices. Everything from tyres, building equipment to toothbrushes might soon be in communications range, heralding the dawn of a new era; one in which today’s Internet (of data and people) gives way to tomorrow’s Internet of Things.

# 4. Driving forces for RFID

As it can be seen in the previous chapters, there are many driving forces for the RFID-technology. One could say that before a group of international retailers with the American WalMart in front put efforts into developing open standards and funded large R&D projects (Auto-ID centre) there was no interest in the technology.

This is definitely not true as many of the examples on the previous pages also document. However, the constant push from the big actors in supply chains has brought development forward to a situation where even small companies in a few years will be able to afford and benefit from the technology.

Looking at the driving forces (most important mentioned first) in the different sectors,

| **Application** | **Driver** |
|---|---|
| Retail | **Efficiency**, logistics, asset management, inventory control |
| Food | **Safety**, quality control, tracking/tracing, logistics |
| US DoD | **Security,** tracking/tracing, efficiency, asset management, logistics |
| Pharmaceuticals | **Authentication**, counterfeiting, theft, inventory control, efficiency, quality control |
| Healthcare | **Identification**, asset management, security |
| Garments - Apparel | **Authentication,** counterfeiting, theft, inventory control |
| Parcels /postal services | **Tracking/tracing**, efficiency, quality control |
| Container tracing | **Tracking/tracing**, efficiency, asset management |
| Airports | **Security,** efficiency |
| Aircrafts | **Product-ID,** maintenance, inspections, quality control |
| Cars and vehicles | **Product-ID,** maintenance, asset management, anti-theft |
| Libraries | **Inventory control**, efficiency, services |
| Animals | **Food safety**, tracking/tracing |
| Beer Kegs | **Asset management**, maintenance, inventory control, efficiency |
| Energy Sector | **Asset management**, maintenance, efficiency, |
| Waste Management | **Environment,** efficiency, asset management |
| Sporting events | **Identification,** security, services |

**TABLE 5**
DRIVING FORCES FOR RFID[FIGURTEXT]

Based on Danish Technological Institute's experience in the RFID field and on discussions in the AUTO-ID forum regarding driving forces for RFID it is clear that there are many similarities in the different industries and going through them a common theme is the economics - behind words like efficiency and logistics lies often cost savings. However, security, safety, theft and counterfeiting are all also very important driving forces for RFID implementations.

One major push for technology has often seen to be governmental regulations and demands from authorities, this is also the case for RFID - food safety, and security regulations are examples of this. Waste and environmental regulations may also be a driver in the future, but this will probably need an even wider spread of RFID-technology into more industries and item level tagging of consumer goods and other materials.

TEKNOLOGISK
INSTITUT

Emballage og Transport
Gregersensvej 5
DK-2630 Taastrup
Tlf.: 72 20 31 50
Tax: 72 20 31 85
et@teknologisk.dk
www.teknologisk.dk/22783
(emballage)
www.teknologisk.dk/22785
(transport)

maj 2016

ISSN 1601-9377