Danish Ministry of the Environment

The potential of RFID-technology to secure information flow between producers of electronics and waste processors

Environmental project No. 1631, 2015

Title:
The potential of RFID-technology to secure information flow be-tween producers of electronics and waste processors

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Published by:

The Danish Environmental Protection Agency
Strandgade 29
DK-1401 Copenhagen K Denmark
www.mst.dk

Year:

2015

ISBN no.

978-87-93283-49-7

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Summary

Increasing population and high growth rates results in a serious challenge in providing adequate resources in the future. High growth results in increasing raw material consumption and waste quantities. This is why, both globally, in the EU and in Denmark there is a growing interest in securing a better utilization of scarce resources by reusing waste fractions.

Scarce resources are used in products such as Electrical and Electronic Equipment (EEE). EU reports document a need for increased recycling rates of Waste Electrical and Electronic Equipment (WEEE), better quality in the recycling of the different WEEE-fractions and reduced losses in the waste handling.

An element in increasing the degree and quality of recycling of WEEE is to establish an improved information flow between EEE-producers and WEEE-processors, which provides the WEEE-processors with knowledge about the products they handle, enabling them to improve the treatment processes.

This report discusses the RFID-technology's potential for improved information flow between EEE-producers and WEEE-processors with focus on optimization of pre-treatment of collected WEEE with the possibility of ensuring a varied flow of information throughout the value chain.

The key questions answered in this report are:

1. Can the RFID-technology deliver the knowledge demanded in the WEEE-processing and in a way, which is compatible with the waste treatment process?
2. What advantages and disadvantages, hereunder economical, will the use of the RFID-technology have for the EEE-producers and the WEEE-processors?
3. What expenses will be related to the use of RFID-technology to ensure the information flow?
4. Which stakeholders are the most relevant in relation to the further work on the RFID-technology to ensure relevant information flow?
5. What are the barriers for realization of the use of RFID-technology to ensure relevant information flow and how can these be overcome?

An overview of RFID-technology is presented with a short description of the RFID-technology in detail, the present technology stage, the scope of application and future development tendencies in Denmark as well as internationally and examples from several business sectors including waste management. Furthermore, a specific overview of the Danish knowhow in the area is presented, including an overview of Danish companies with competences in the field and national development projects.

To understand how the information flow between EEE-producers and WEEE-processors currently is working and how RFID-technology might help improve the information flow, WEEE-processors have been visited and interviewed to gather first-hand information

about the WEEE-pre-treatment processes, the WEEE-processors' needs for information and the barriers they see for setting up a proper information flow.

Based on the WEEE-processors' responses, interviews with EEE-producers have been conducted to understand which information they already have available, what the quality of this information is, what relevant information the EEE-producers could make available in the future and what the barriers for this is. During the interviews, the companies have also been asked to reflect on the consequences for them of using the RFID-technology.

Answers from WEEE-processors and EEE-producers including the barriers mentioned by them is analysed and discussed in the light of a possible set up of a system, similar to systems already in use in other industries e.g. the automobile dismantling industry. Barriers for the use of, and myths around, RFID-technology are discussed and solutions to overcome these barriers are set up.

The conclusions are as follows:

WEEE-processors need detailed and updated knowledge at component level about the presence of substances and materials. EEE-producers are willing to supply the information they regard as non-confidential. Further mapping of exact data requirements is needed followed by discussions about means to exchange this information.

Detailed knowledge of the individual product unit is needed in order to get a sound recycling and sorting of WEEE. Both WEEE-processors and EEE-producers mention RFID-technology as a promising means to achieve a high level of information exchange between the two.

It is possible to build up a RFID-technological solution based on UHF EPC Gen2 technology, which can handle the information requested by WEEE-processors and provide an efficient information flow and knowledge sharing between EEE-producers and WEEE-processors. Based on experience from other industries it is considered able to function in a WEEE-context too.

A full-scale RFID-technology based system to manage WEEE needs to be standardized on EU level as a minimum – preferably on a global scale. A system like this should be administered in collaboration between involved partners including an independent operator who should manage the system set-up and handle electronic communication and administer development in close connection with the industry.

The main barriers for building a RFID-based solution is not technological but a matter of how information can be made available, agreement and organization of databases and the willingness to cooperate on a global scale on exchanging vital information for the benefit of society and partners in supply chain.

Another main barrier is the difficulty in proving the economic feasibility for a technological solution including RFID and development of databases for the sole purpose of WEEE-handling. An RFID-project will capitalize at the earliest after 5-10 years, as EEE needs to be marketed and reach its End of Life stage before the WEEE-processing benefits can be harvested.

Barriers and myths should be overcome by setting up business cases that convince all involved parties of the opportunities and benefits closely followed by thorough information about the RFID-technology.

A calculation on return on investment for a full RFID-installation will be very difficult to set up at present stage.

The main recommendation is to organise pilot projects as follows:

1. Organization of a demonstration project involving leading Danish ICT-developer (with RFID-technology knowledge) and a number of EEE-manufacturers and WEEE-processors including research and development (R&D) partners.
2. Setting up R&D projects on,
    a. Standardized data on EEE-product level
    b. IT-infrastructure in a WEEE-database
    c. Efficiency of the WEEE-processes related to utilizing raw materials
    d. Overall organization of a future WEEE system including RFID technology
3. Forming groups of stakeholders within WEEE-processing and EEE manufacturing including organizations also representing international and European interests.

1. Introduction and method

Increasing population in the world and high growth rates implies increasing material consumption and growing waste generation. Providing adequate resources is an increasing and serious challenge. This is why there, both globally, in the EU and in Denmark is a growing interest in securing a better utilization of scarce resources by recycling and reusing waste.

Electrical and Electronic Equipment (EEE) is produced and marketed in increasingly growing quantities. Both the life span and the prices of the products are becoming lower, which results in drastically increased quantities of Waste of Electrical and Electronic Equipment (WEEE).

In addition, EEE contains a long range of problematic substances, which have a damaging impact on humans and the environment. The problematic substances includes mercury, lead, cadmium, chromium and halogen substances such as chloro-fluoro-carbon (CFC), brominated flame retardants (BFRs), polychlorinated biphenyls (PCBs) and Polyvinyl Chloride (PVC).

EEE also contains a long range of valuable materials such as cobber, platinum, palladium, germanium and neodymium, which from a resource point of view should be recycled in production of new equipment.

It must be ensured that these materials are not lost in the WEEE-treatment processes, but are recycled back into the production of new equipment. Therefore there is a desire to optimize the recycling of the materials in WEEE, so that the overall resource consumption can be reduced. More and better recycling of WEEE could contribute to a significant reduction in the quantities of WEEE, which otherwise is incinerated or disposed of in landfills.

It must thus be ensured that the handling of worn-out equipment is carried out under controlled conditions. At the same time, it must be prevented that WEEE is illegally exported to parts of the world, where it cannot be ensured that the handling is carried out in an environmentally safe and resource-saving manner.

1.1 Producer responsibility for WEEE

Based on the above-mentioned conditions the EU has appointed WEEE to be a prioritized waste stream, which demands a special effort by way of the WEEE-directive (WEEE-directive, 2012).

The objective of the WEEE-directive is on the one hand to encourage manufactures to produce environmentally friendly products and on the other hand to increase reuse and recycling of WEEE.

EU has chosen the concept of “producer responsibility” as the overall principle for achieving the objectives. Therefore, producer responsibility is the basis for the WEEE-directive.

In Denmark the Danish Producer Responsibility system (Dansk Producentansvarssystem (DPA-System)) manages a system that handles registration of EEE-producers/importers and statistics on the marketing, collection and treatment of WEEE.

The 2012 statistics for Denmark show 62,7 % collection of WEEE[1] from households compared to an average of EEE placed on the market the previously three years. Between 79-96 % of the WEEE is recycled. The percentage depends on the type of WEEE handled and is a measure for the quantity of waste that are handled and not the quality of the recycling. The revised WEEE-directive from 2012 sets goals for recycling of the increasing amount of WEEE and put more focus on the output of the recycling processes. The EU Commission concludes that at least 14 materials are critical for the EU from a resource point of view[2]. Many of these 14 materials are present in WEEE, but the recycling grades of these are generally quite low[3]. There is therefore a need for higher efficiency in collection and recycling of WEEE and for higher quality of the sorted fractions.

1.2 A need for information-flow between EEE-producer and WEEE-processor

An element in increasing the degree and quality of recycling of WEEE is to establish an information flow between EEE-producers and WEEE-processors. The information can e.g. concern placement of critical resources and hazardous substances in the products, or instructions on how the products can be separated into fractions for recycling in connection with pre-treatment of the waste.

Pre-treatment is the process performed at the first step WEEE-processors' facility, where the hazardous and statutory substances/materials/components and other components from the WEEE are removed, followed by a rougher further dismantling and sorting of the remaining parts of the WEEE into different waste fractions. The waste fractions are typically processed outside Denmark e.g. metal recovery in large smelters. The companies conducting the smelting process demands a certain quality of the waste and pay dependent on the quality of the materials that is received.

To obtain higher quality of the WEEE fractions in the dismantling and sorting-process, it is paramount that WEEE-processors get detailed product information. This information is most rationally provided by the EEE-producers.

The WEEE-directive has foreseen the need for information exchange between the parties and the requirement is implemented in the Danish order nr. 130 of 06/02/2014:

49.-(1) Producers shall make necessary information about preparing for re-use and treatment of electrical or electronic equipment available free of charge for each type of new electrical or electronic equipment being placed on the market in the EU for the first time and by no later than one year after it was first placed on the market.

(2) To the extent that this is necessary for facilities, which are preparing for re-use, as well as treatment and recycling facilities, cf. the Statutory Order on Waste, to be able to comply with the provisions in the Act and this Statutory Order, the information, cf. subsection (1) shall identify the different components and materials in the electrical or electronic equipment as well as the location of hazardous substances and mixtures in the

[1] DPA-System, 2013, *WEEE og BAT statistik 2012*, http://www.dpa-system.dk/da/WEEE/Producentansvar/Statistik-2012
[2] Ad-hoc Working Group on defining critical raw materials 2010, *Critical raw materials for the EU - Report of the Ad-hoc Working Group on defining critical raw materials*, The European Commission - Enterprise and Industry. ec.europa.eu/enterprise/policies/raw-materials/files/docs/report-b_en.pdf
[3] Smith, Morten, 2011, *E-skrot, en kilde til kritiske metaller?* Roskilde Universitet, Roskilde. pp. 56-57

electrical or electronic equipment. The information shall be made available to facilities, which are preparing for re-use, as well as treatment and recycling facilities by producers of electrical or electronic equipment in the form of manuals or by means of digital media (e.g. CD-ROM, online services).

The requirement is not very specific e.g., substances, detail level, form etc. and the information flow from EEE-producers to WEEE-processors is estimated to be rather limited today.

A challenge in this context is among others to find a system for the information flow, which is compatible with the way the waste management process is carried out. Several actors point to the use of RFID-tags as a possible future technological solution to implement such an information flow.

Besides providing valuable information to the WEEE-processors one could imagine that the technology could be carrier for varying sets of information related to product status, business statistics, logistics, service, product information etc. of great value for different actors in the value chain such as the producer, the retailer, the service provider, the transportation company, the end-users/consumers etc.

1.3 Previous studies on RFID-technology and WEEE

The use of the RFID-technology in regards to securing relevant information flow between producer and waste-handler is not new. Two reports published internationally in respectively July 2003[4] and November 2006[5] deal with the same topic. The reports are conducted by the European Committee for Electrotechnical standardization (CENELEC) and the producer trade organisation CECED. The key conclusions from the CECED report are:

- No tagging system currently available or available in the near future will meet the current operational requirements for disposal and logistics of WEEE.
- There is no clear financial case for adopting a tagging system in the short term (10-15 years). Having made substantial up-front investment then tagging may offer financial benefit over a 20-year plus period for large goods.
- The major hurdle to adoption of tagging is the acceptance of the investment and operational changes required by other stakeholders such as disposal companies and local authorities.
- Do not adopt a tagging solution to address WEEE and RoHS for the present
- Investigate other means of management of disposal costs associated with the WEEE directive.

The report from 2006 builds upon the CECED report, and it is stated that it has not been possible to determine any progress in RFID-technology which significantly changes the conclusions of the CECED report and that the key conclusions from the CECED report is still considered valid. This is supplemented with the following conclusions:

- Utilization of machine-readable product ID identification for WEEE management is dependent on it being applied during production. The introduction of machine-readable product identification technologies cannot solely be introduced for WEEE

[4] ELECTRONIC PRODUCT IDENTIFICATION - A Study into the feasibility of technologies that enable the identification of producer and product characteristics – CECED - Steve Chambers, Dr Valerie Scott, Dr David Stocks, Dr Nick Collier, Mark Cohen, Scientific Generics Limited, Cambridge CB2 5GG, 4th July 2003

[5] Smart tracker chips - Feasibility study on the inclusion of RFID in Electrical and Electronic Equipment for WEEE management, TECHNICAL REPORT - CLC/TR 50489, November 2006

management purposes but needs wider consideration of all needs and limitations along the product life cycle.
- There are no technical and economic grounds for implementing RFID for waste management.
- The RFID-technology is evolving and due to this fact the issue should be reviewed within the next 3-5 years or as soon as RFID at item level is used widely.
- According to current knowledge and the return on investments, the use of RFID for only waste management purposes is not economically feasible. RFID use for WEEE management needs to be an integrated part of automatic products identification during the whole product life cycle and by its included actors. To be able to justify RFID for waste management the system should be build on existing RFID-applications such as supply chain management. However, until technology and standards in these other applications can become stable then RFID for waste management cannot be considered.

Since 2006 further development of the technology have taken place and this makes it relevant to investigate the technology once again. Examples of technology developments that could challenge the above conclusions are:

- RFID-tag prices have reduced dramatically and RFID-reader performance efficiency has improved
- International standards have been developed and introduced related to identifying, capturing and exchanging data in value- and supply chains
- It is possible to read RFID-tags across national borders without changing tags or readers, which is important in all international trade and logistics.
- A huge number of ICT-solutions have been implemented including RFID-technology within
  - Tracking and tracing in supply chain
  - Warehouse and inventory management at case and pallet level
  - Asset management – containers, load carriers, equipment

The objective of this report is to make a screening of the RFID-technology in order to uncover the potentials of the RFID-technology to contribute to ensuring a relevant information flow between EEE-producers and WEEE-processors. The focus is on optimizing the pre-treatment of the collected WEEE by supplying a flow of information throughout the value chain from EEE-producer to WEEE-processor.

1.4 Questions of interest

To understand how the information flow between EEE-producers and WEEE-processors is currently working and how RFID-technology might help improve the information flow, interviews with the WEEE-processors have been conducted concerning:

- What knowledge is required in order to optimize WEEE-treatment and increase re-use and recycling?
- What are the companies' bid on how this knowledge can optimally be made accessible and useable for the companies' waste treatment process?
- Can the RFID-technology provide the knowledge, which is required in the waste process and in a way which is compatible with the waste management process?
- What advantages and disadvantages, including economic, will the use of RIFD-technology have for the WEEE-processors?
- Which barriers do the WEEE-processors see for realizing the use of the RIFD-technology, and how can these barriers be overcome?

Based on the WEEE-processors responses to the questions mentioned above, interviews with EEE-producers have been conducted concerning:

- What information do EEE-producers today make available for WEEE-processors?
- Are the EEE-producers able to provide the knowledge which is requested by WEEE-processors and in the requested form?
- Can the data be made accessible in one or more databases?
- Who should own and administrate these databases?
- Would the EEE-producer be able to RFID-tag their products sold in the EU?
- Which barriers are there for using RFID as information facilitator between EEE-producers and WEEE-processors?
- Which economic consequences can be foreseen using RFID-technology?
- Which opportunities do EEE-producers see in using RFID-technology?
- Is RFID-technology considered in other applications?

1.5 Method for examination of the RFID potential

1.5.1 RFID-technology – an overview

The intention of chapter 2 is to explain what RFID and RFID-technology is and to give an update on the RFID-technology including the specific use of the technology.

A short description is drawn up on the RFID-technology, including the present technology stage, scope of application and future development tendencies in Denmark as well as international. A specific overview of the Danish knowhow in the area is made, including an overview of Danish companies with competencies in the area, national development projects and the like.

The technology overview is based on knowledge from the Danish Technological Institute's Auto-ID – RFID test- and knowledge centre as well as updated knowledge from the Danish Technological Institute's international network, which is part of the centre Packaging & Logistics (P&L´s) network and RFID-expert panel. The mapping will give an updated overview of frequency ranges, use and current users of the technique in full scale and in pilot projects and more.

In Annex 1 the RFID-technology is furthermore presented in more detail.

1.5.2 Interviews with WEEE-processors

WEEE-processors have been visited and interviewed to gather first-hand information about the WEEE pre-treatment processes and the information needs of the WEEE-processors. Two relevant Danish WEEE-processors have been selected. One criterion for the selection of WEEE-processors to be interviewed has been that they must handle fraction 3 and 4 (see table 1). This is because these WEEE-fractions are evaluated to contain the most critical and valuable resources for recycling.

The five WEEE-fractions cover equipment from the following categories:

Danish collection fractions	WEEE category
Fraction 1: Large household appliances	1, 6, 7
Fraction 2: Cooling equipment	1
Fraction 3: Small household appliances	2, 3, 4, 5a*, 6, 7, 8, 9
Fraction 4: Screens and monitors	3, 4, 7, 9
Fraction 5: Light sources	5b**

Table 1
DANISH COLLECTION FRACTIONS AND THE WEEE CATEGORIES (BEK NR 1296 OF 12/12/2011)
* luminaires **light sources. Category 10 is not considered WEEE from households[6]

The size of the company (amount of WEEE processed/year) and whether the WEEE-processor is doing business internationally has influenced the choice.

After the selection of WEEE-processors a questionnaire to support the interviews was developed, see Annex 2. The companies were visited and processes, technologies and systems were evaluated in parallel with the execution of interviews, with the aim to understand the existing technology and information needs.

The two WEEE pre-treatment processors selected for interview has been Stena Technoworld AB, Bräkne Hoby, Sweden, represented by Mr. Sverker Sjölin and Averhoff A/S in Risskov, Aarhus, Denmark, represented by Mr. Tom Ellegaard. The companies conduct pre-treatment of WEEE collected in Denmark. Stena Technoworld AB also treats WEEE collected in Sweden.

Interviews were performed at Stena Technoworld AB on March 26, 2013 and at Averhoff A/S on April 5, 2013 and followed by questions for clarification via telephone.

Chapter 3 present the results of the interview and the information needs expressed by the WEEE-processors.

1.5.3 Interviews with EEE-producers

To understand what information the EEE-producers already have available, the quality of it, what relevant information the EEE-producers could make available in the future and what the barriers for this is, interviews with three EEE-producers has been conducted. During the interview the companies was also asked to reflect on the consequences for them of using the RFID-technology.

One big global foreign EEE-producer and two smaller Danish EEE-producers working on a global scale has been selected for interviews. A foreign company means a company whose head office is abroad.

[6] DPA-System, 2013, *WEEE og BAT statistik 2012*, www.dpa-system.dk/da/WEEE/Producentansvar/Statistik-2012 (in Danish)

A questionnaire, see Annex 3, were developed based on the interviews with the WEEE-processors and present legal requirements. The EEE-producers are kept anonymous in this report, as they have requested this.

Chapter 4 contains a presentation of the results of the interviews.

1.5.4 Discussion and possible set-up for RFID-technology and WEEE

Based on the knowledge from the updated technology overview and the information from the interviews with the EEE-producers and WEEE-processors the potential of the RFID-technology is discussed and a possible set-up of a system using RFID-technology is put forward. The following questions are answered:

- Can the RFID-technology deliver the knowledge demanded in the WEEE-processing and in a way, which is compatible with the waste treatment process?
- What advantages and disadvantages, hereunder economical, will the use of the RFID-technology to ensure information flow have for the EEE-producers and the WEEE-processors?
- What expenses will be related to the use of RFID-technology to ensure the information flow?
- Which stakeholders are the most relevant in relation to the further work on the RFID-technology to ensure relevant information flow?
- What are the barriers to realize the use of the RFID-technology to ensure relevant information flow and how can these be overcome?

The Danish Technological Institute organized a workshop with a project reference group consisting of stakeholders in Denmark in the WEEE-context. The aim of the workshop was to have the stakeholders point of view on the RFID-technology as information carrier from EEE-producer to WEEE-processor and to investigate concerns, challenges and solutions.

The Danish Technological Institute presented the preliminary findings from the interviews and a suggestion to a system solution to handle the information exchange between the EEE-producers and WEEE-processors. This inspired to a discussion of concerns, challenges and solutions with the outcome of some concerns but also several ideas and suggestions to solutions.

In short, the workshop showed that there are varying views among WEEE-processors about whether increased transfer of information by means of the RFID-technology can have an effect on the recycling of WEEE. All participants at the workshop agreed that the main challenge would be the organization and maintenance of an international database-system.

The workshop was held on May 16, 2013 at Danish Technological Institute where the following were represented:

- The Danish Environmental Protection Agency (Miljøstyrelsen) - Anne Harborg Larsen, AC-Technician
- DPA-system –The Danish Producer Responsibility System - Ulf Gilberg, Secretary Manager
- The Association of Danish Recycling Industries - Poul Bengt, Sales Manager Metal group, Ragn-Sells Recyclables AB
- BFE – The Danish Consumer Electronics Association - Johs Chr. Johansen, Communications Manager

- GS1 Denmark[7] -Sacha Mendes da Silva, Market Development Manager, GS1
- Danish Technological Institute - Packaging and Logistics
  - Finn Zoega, Section Head of Logistics,
  - Henrik Hansen, Senior Consultant,
  - Morten Pedersen, Senior Consultant,

[7] GS1 is a global standardization organization. GS1's main activity is the development of the GS1 System, a series of standards designed to improve supply chain management

2. RFID-Technology - an overview

RFID (Radio-frequency IDentification) is an important automatic identification technique with a great potential within a number of industries. The following description will give a short overview of the technology and the business opportunities. A more detailed description is given in Annex 1.

The information in this chapter is fully based on the knowledge and competences of the Scandinavian Auto-ID Center at the Danish Technological Institute. The references for the statements in this chapter are therefore the Danish Technological Institute, 2013.

2.1 RFID-technology

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, track and trace in logistics etc.

RFID is today one of the major evolutions in computing. It is a technology that connects objects to the internet or databases, so they can be tracked and companies can share data about products and items. 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 concept is simple: Place a transponder (a microchip with an antenna) also called a RFID-tag on an item and then use a reader (a device with one or more antennas) to read data off the microchip using radio waves. The reader passes the information from the RFID-tag to different computer systems, so that the data can be used to create business value. The business value is created because the technology can help improve data accuracy by tracking products through the supply chains and by identifying products and items/objects at specific points in the supply chain. The technology enables the detection and identification of tagged objects through the data it transmits.

2.1.1 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. 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 automatic readers and does not require labour.

RFID-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 much more information than the barcode.

2.1.2 RFID-tags (transponder)

RFID-tags can stand both heating and cooling to some extent. Standard RFID-tags can stand temperature up to 80°C and can therefore be used in most production processes. Compared with the barcode RFID-tags are however far more fragile because liquids and rough handling can damage readability.

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.

IMAGE 1
RFID-TAGS - PASSIVE

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 – they get the power they need from the RFID-reader. The active tags have a power supply like a battery, enabling the tag to emit 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.

2.1.3 Passive RFID

Passive RFID-tags have no power source and no transmitter and is also called Class O or Class I. They are cheaper than active tags 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 centimetres to 5-6 metres, depending on the frequency).

A passive RFID-tag consists of a microchip attached to an antenna. The tag 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. Tags can also be embedded in a plastic card, a key fob, the walls of a plastic container or special packaging to resist heat, cold or harsh cleaning chemicals. Packing the tag like this 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 and are less expensive than the more powerful active tags.

Passive tags can operate at low frequency (LF), high frequency (HF) and ultra-high frequency (UHF). Radio waves behave differently at each of these frequencies, which means that the different frequencies are suitable for different applications. They can penetrate most materials, but cannot go through metal. Low-frequency tags are ideal for applications where the tag needs to be read near 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 products and cases in the centre of a pallet, or on materials, products and objects made of or containing metal or water.

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 5-6 meters for RFID to be useful in a warehouse. Low-frequency tags can usually be read from within distance of 30 cm or less - usually 10 cm. High frequency tags can be read from 0-50 cm, and UHF tags can be read from 1-6 meters or more.

2.1.4 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). The active tags are more expensive. 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.

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.

2.2 RFID-systems and -solutions

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. RFID-tags, both passive and active, also have the ability to monitor, measure and record numerous environmental conditions, when combined with a sensing device.

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.

2.2.1 GS1 EPCglobal - presently UHF and HF

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 for tag data, interface, protocols and information services 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.

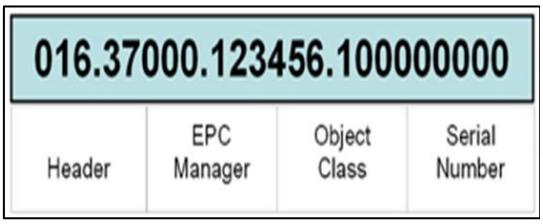

IMAGE 2
ILLUSTRATION OF AN EPC [8]

GS1 Electronic Product Code (EPC) is the next generation of product identification and supports the use of RFID. The EPC is a unique number which identifies a specific object in motion in the supply chain[9]. Using an EPC makes it possible to have unique identification of all products. EPC is divided into numbers which can identify the manufacturer and product type, and it uses a serial number to identify unique items. The EPC is attached to a tag and by using RFID, EPC can communicate its number to a reader, which passes the number on to a computer system. When a tag is encoded with EPC it will allow the pallets, cases or individual items to be tracked through the supply chain that are typically international.

The GS1 EPCglobal Network 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 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.

GS1 EPCglobal illustrates the data capturing process like this:

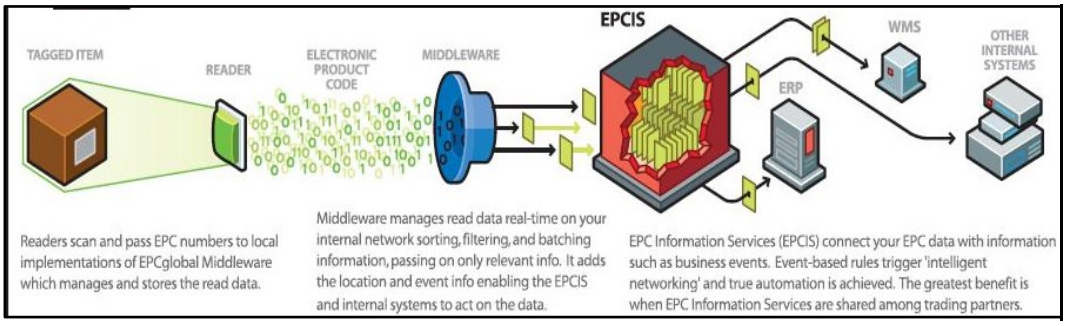

IMAGE 3
THE DATA CAPTURING PROCESS

The RFID-system consists of three basic components as illustrated above:

- Tag, consisting of a semiconductor, an antenna and in some cases a battery and a memory capacity.
- Reader/scanner consisting of an antenna, an electronic radio frequency and control module.
- Control unit usually consisting of a computer with some sort of software for database.

[8] www.epc-rfid.info/
[9] www.gs1.org/epcglobal/about

2.2.2 Security and Privacy

One of the 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.

If all products 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. With a technology as ubiquitous as RFID can be, there is a 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.

There have been some discussions on security breach related to an RFID-deployment but so far no actual examples. Vendors and customers 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. A number of security measures already exist and the good news is that the industries are paying more attention to the security issue. However, much research and developments are still needed in this field.

RFID is usually associated with the retailing and manufacturing industries because these industries have been driving developments presently taking place. The major retailers - WalMart, Tesco, Metro etc. - all have set up huge implementation plans for their RFID-projects in supply chain on pallets and cases. However, a number of other industries already have applications running and some have had that for a longer period. Some of the leading industries today in adopting RFID-technology are retail and food industry, US Department of Defence, Pharmaceutical industry, Healthcare industry and Garments/ Apparel industry. For a list of concrete examples of the use of RFID-tags in supply chains and information exchange in a variety of sectors, see annex 1.

2.3 Examples of RFID in 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.

2.3.1 Collection of municipal waste in Kristiansand, Norway [10]

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 utilizes RFID-based data to track the quantity and type of waste collected. The RFID-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 vehicles' on board host controller and transferred later to a central waste management system.

[10] AMCS Group, UK – www.amcsgroup.com/uk/

In communities with these pay-as-you-throw (PAYT)[11] 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.

2.3.2 Recycling of printers in Brazil

HewlettPackard in Brazil[12] (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 is 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. However, the EPC data on the tag will identify which plastics can be recycled and which will need to undergo other forms of waste treatment. The experience from this project is that most tags are still functioning after 5-6 years.

2.3.3 Dansk Retursystem – deposit refund on bottle and cans[13]

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.

[11] en.wikipedia.org/wiki/Pay_as_you_throw

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

[13] www.pantstation.dk at Dansk Retursystem (in Danish)

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[14] have delivered the software and RFID-tags.

2.4 Danish RFID-suppliers and solutions providers

In Annex 1 is a table that gives an overview of some major Danish actors[15] within the RFID-technology and a detailed Review of the Current State of RFID with description of the technology in detail and examples from several business sectors.

Some of the presently more experienced Danish suppliers of RFID based solutions are:

Company	Services	Cases
Lyngsoe Systems A/S Danish	Services and solutions Software development and systems integration of logistics solutions. Systems design, installation maintaining control and track-and-trace systems. WMS and WCS. Automaton of sorting and distribution centres. Warehouse logistics and traceability	Postal solutions Post DK, Airport solutions in Aalborg, Hong Kong, Milan Malpensa, Library solutions- Kolding, Hamburg and at least 8 others Supply Chain solutions
2Trace Danish	Services and solutions Software, reading and integration in ERP systems Development of 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 Berendsen Textile - tack and trace, inventory management
IBM Denmark ApS	Services and solutions Systems in a wide range of applications	Container Centralen – container tracking Many international cases
PCSYS Danish	Services and solutions Provides complete RFID-solutions including consultancy, total supply of hardware, software, installation, integration with ERP, WMS and shop floor systems within - Inventory management, Preventive maintenance	Danfoss Drives – quality and production management Icopal – inventory management , theft prevention

TABLE 2
MORE EXPERINECED DANISH ACTORS WITHIN THE RFID-TECHNOLOGY

[14] Suppliers: Antenna - Prosign RFID, Struer, Denmark, Labels and tags - RF-Labeltech, Randers, Denmark, Software – Grontmiij, Glostrup, Denmark
[15] The list is not complete, but contains some of the important suppliers related to major implementations

3. Mapping of knowledge requested by WEEE-processors

3.1 Short description of WEEE treatment processes

The two WEEE processors visited and interviewed during March and April 2013 were Averhoff A/S in Aarhus, Denmark and Stena Metall AB in Bräkne-Hoby, Sweden[16].

The processing of WEEE differs somewhat between the two companies.

Stena Metall AB receives containers with a mix of WEEE fractions 3 and 4 while Averhoff A/S receives containers with pure fraction 3 and fraction 4 (See chapter 1 for definition of fractions).

Stena Metall AB uses manual pre-treatment of the WEEE to sort it into different waste fractions which are sold to processors or companies doing subsequent disintegration separation and recovery. At Averhoff A/S pre-treatment as well as shredding and sorting in the different waste fractions presented below is made at the same location before they are sold to processors outside Denmark doing recovery.

Overall, the basic techniques are the same and it is assumed that this is the same for all Danish treatment facilities for WEEE.

The containers are emptied onto a conveyor belt followed by manual treatment which involves dismantling and sorting for removal of environmentally harmful and hazardous substances and components. This is followed by a mechanical treatment in a chain crusher which disintegrates the WEEE. Dust is extracted before the crushed equipment passes the mechanical sorting mechanisms in the form of magnetic separation, eddy-current, further dust extraction and at Averhoff A/S a final manual sorting of the remains not sorted out in the automatic sorting is done.

The result is the following waste fractions:

- Metals (copper, iron, aluminium, steel etc.)
- Plastic (PVC, ABS, PC etc.)[17]
- Printed circuit boards (of varying quality/grade)
- Cables (in different grades)
- Glass (cathode ray tube, flat glass)
- Hazardous waste (dust from the process, batteries, mercury, beryllium, PCB-containing products and components etc.)
- Other packaging (paper, cardboard etc.)
- Wood

[16] Se overview of Interviews in the referencelist.
[17] Polyvinyl Chloride (PVC), Acrylonitrile Butadiene Styrene (ABS), Polycarbonates (PC)

The fractions are somewhat cross contaminated due to the sorting technique. The separation and sorting technique used is a result of the design of the EEE. Product design is in most cases not focused on easy dismantling and proper separation combined with constraints in the dismantling process technology in use. Both companies have a strong focus on cost reduction and optimizing of labouring processes.

3.2 WEEE-processors need for information

For a list of the questions put forward to the WEEE–processors, see Annex 2.

To ease the reading of this chapter the terms product, part and component are clarified: A TV set is a product, a printed circuit board is a collection of components i.e. a part on which components are mounted.

3.2.1 General information

To allow WEEE-processors to increase quantity and quality of recycling the information according to the interviewed WEEE-processors needs to be:

- The right information
- On the right place
- At the right time and
- In the right form

3.2.2 Right information

According to the WEEE-processors the right information is information that creates value in the waste process by increasing the amount of waste that can be sold for recycling processes. More specifically information need's concern:

- What substances/materials that are present in the WEEE
- The quantities/concentrations (e.g. mg/kg)
- The chemical form of the substances/materials
- The location of the substances/materials

The information should be:

- Detailed
- On component level and
- Valid and updated

It is essential for the WEEE-processors to know the presence of substances and materials in the WEEE including the substances and materials harmful to the environment and/or human health. This is necessary in order for the WEEE-processors to determine whether to recycle a specific product, part or component or not. The WEEE-processors need to know things like whether or not there is e.g. lead, bismuth or beryllium in the product, the type of fluorescent powder in fluorescent lamps, whether or not the product contains a specific type of bromated flame retardant (there are different types) or the placement of critical and valuable resources such as rare earths, gold, silver and platinum. This kind of information will make it possible for the WEEE-processors to detect and conduct an effective removal of the harmful substances and increase the recycling of the valuable ones.

Over time the view on environmental-, hazardous- and resource aspects of substances and materials will change. Some will change from being regarded as not problematic to problematic and vice-versa. Therefore the requirements for WEEE-processing will most likely

change over time. WEEE-processors believe it would be optimal to have a full listing of all substances and materials in each marketed EEE-product so the WEEE processor several years later at the end-of-life for the specific EEE can detect the problematic and critical materials and react accordingly.

Information about content is a criteria for the decision to recycle a product, part or component or not, and a criteria for decisions on how to recycle. But also it can be used to get a more accurate cost/price estimate of the sorted fractions resulting from the pre-treatment process and thereby increase the value of the different waste fractions because the value can be estimated more accurately.

According to the WEEE-processors the information needs to be quite detailed. There may in some cases be information about content on the EEE-producer's websites, but according to the interviewed WEEE-processors, few producers specify content on sufficient level of detail. As an example it is not enough to know the weight percentage of a printed circuit board in a mobile phone. Information on component level with specifics the components' type, their composition etc. is necessary.

The WEEE-processors need also to know the chemical form e.g. gas, liquid, solid of the substances and materials to be able to handle them properly.

The location of the components, substances and materials is needed for safe and rational removal of the components and materials. This could be specified on drawings, sketches, pictures or "exploded view drawing". Image 5 shows how explosive drawings are done in the International Dismantling Information System for cars (IDIS) which is further described in chapter 5. Example taken from the automobile industry in lack of similar example from the EEE-industry.

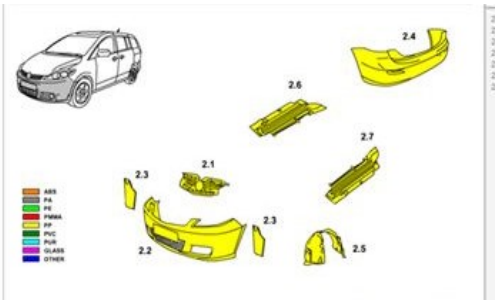

IMAGE 4
EXAMPLE OF EXPLODED VIEW DRAWING

New designs, models and modifications of EEE-products take place with increasing rates. WEEE-processors stress the need for access to updated, valid and correct data about the EEE-products when they become waste.

The WEEE-processors express that next to legislation, economy is the biggest driver for their business. Decisions related to investments in new or upgraded techniques and processes to optimize recycling undergo rational technical/economical evaluations based on e.g. Return on Investment. Solving this equation requires detailed and reliable knowledge of the presence and content of substances and materials in the product now as well as in the future.

3.2.3 Right Time

According to the WEEE-processors the information should be available in due time before new EEE-products reach the WEEE-processor which allows the processor to adapt to processing of new designs, substances and materials and other relevant changes in products. Furthermore, the relevant information should be available during daily production when the individual product is processed so that the information can be integrated in daily operations for technical as well as administrative purposes.

3.2.4 Right Place

The WEEE-processors express a need for direct access to specific product information from the EEE-producers. The information should be available at the production areas and offices of the WEEE-processors to trigger downstream processes, improve administrative processes etc. The data do not necessarily need to be physically present at the WEEE-processors' location but the data should be accessible electronically from the EEE-producers e.g. through direct database access at the production premises.

The WEEE-processors considered it the most rational and effective way that the EEE-producers administer their own database and keep it updated.

3.2.5 Right form

The WEEE-processors also point out that information should be available in electronic and standardized form (see below). The individual products could for instance be marked with readable tags that do not require line of sight.

The WEEE-processors consider the RFID-technology linked up to valid and updated databases a promising solution as information carrier between EEE-producers and WEEE-processors as it contrary to bar codes do not require line of sight and are less sensitive to wear and tear.

The WEEE-processors see the RFID-technology as a must as the RFID-tag can be used to gain access to databases containing information concerning WEEE suited for reuse of components or recycling of materials.

The WEEE-processors stress the importance of standardized means of exchanging material compositions data and request an industrial standard for this. There are many advantages by using standards. The use of standards facilitates the use of uniform terminology and improves accuracy and consistency in materials description. It can be a basis for developing standardized protocols to ease the transfer and processing of data. Standards ensure effective exchanges between companies, and act as basic guidelines that facilitate interoperability and provide structure to industries.

Some standardization work has been conducted in relation to material declarations for products of companies operating in and supplying the electrotechnical industry[18]. The standard IEC 62474:2012 "*Material declaration for products of and for the electrotechnical industry"*[19] is an example of this covering both organic and inorganic materials. The electrotechnical industry and its supply chain use material declarations to track and declare specific information about the material composition of its products. To harmonize requirements across the supply chain and to improve processes, IEC 62474 provides an international standard for the exchange of material composition data and provide requirements for material declarations. This international standard benefits the electrotechnical industry by establishing requirements for reporting of substances and materials, standardizing protocols and facilitating transfer and processing of data.

The standard is interesting as it deals with standardization of the means of transfer of material composition data within the electro technical industry and should be included in future work on a standard for standardized means of exchanging material compositions data in EEE/WEEE.

[18] A sector of the economy in which an aggregate of commercial enterprises is engaged in the design, manufacture and marketing of machinery, apparatus and supplies for the generation, storage and utilization of electrical energy, such as household appliances, radio and television receiving equipment, and lighting and wiring equipment. (Source: SIC)

[19] IEC 62474:2012 "*Material declaration for products of and for the electro technical industry-CENELEC* webshop.ds.dk/product/M250142/dsen-624742012.aspx

3.3 Barriers for use of RFID-technology

The WEEE-processors express the following major barriers for the RFID-technology as means of exchanging information between the EEE-producers and the WEEE-processors:

- some EEE product data is regarded confidential i.e. too sensible to share widely
- some EEE-producers do not see the value of a RFID-solution and have no motivation to keep data updated
- lack of uniform standardized ways of transferring the relevant data
- to the extent databases exist they are not valid, updated and detailed enough
- low readability of the RFID-tag on metal or in moist environment
- incompatibility of RFID-tag material with the material it is fixed to e.g. when a plastic component attached with an RFID-tag is grinded up the plastic granules is contaminated with the RFID-tag material e.g. cobber from the antenna resulting in low grade plastic not suited for recycling
- violation of privacy – can RFID-data be linked to personal data?
- expenses related to process and layout changes e.g. modifications of off-loading and feed systems to separate the WEEE pieces to obtain proper reading of RFID-tags, installation of readers, development of software, employee training in the use of new technology, maintenance etc.

4. What information can EEE-producers provide?

In the following the results from the interviews with EEE-producers are presented and discussed. The questions and answers from the EEE-producers are presented one by one and followed by a discussion of how the information that the EEE-producers provide can match with the needs expressed by the WEEE-processors The interviewed EEE-producers have asked for anonymity and is therefore referred to as Company A, B and C in this chapter[20].

4.1 EEE-producers - Questions and answers

What WEEE-information is available for waste processors today, how is it accessible and at what detail level?

The EEE-producers interviewed report varying degree of accessibility of information related to the WEEE-processors.

Company A reports that it "*makes information available to recyclers based on the proposal agreed between the European Information & Communications Technology Industry Association (EICTA i.e. Digital Europe), the European Committee of Domestic Equipment Manufacturers (CECED) and the European Electronics Recyclers Association (EERA). This defines the content recyclers specified*" (Company A, 2013).

The proposal that the company is referring to is a joint position guidance dated September 2005, see annex 4. The joint position guidance constitutes an agreement between organisations of EEE-producers and WEEE-processors to make certain information available for WEEE-processors. In the joint position guidance, it is stated: "*Each producer creates an access point for recyclers to post questions in relation to his products, typically an alias to be used on the producer's internet site. A producer, upon request from a recycler dealing with one of his equipment put on the market after August 13th 2005, provides information on "positive presence" of materials and components as listed in Annex A at product level or product family level. Other questions will be handled on a "reasonable effort" mode*".[21]

Further the guidance document specifies English as the language mode and that the format is up to the EEE-producers. Sketches and pictures are suggested to ease the responses.

Company A has also established a uniform global management standard for internal use to control environment related substances in parts and materials to be used in their prod-

[20] The Danish EPA has been informed on the names of the specific companies interviewed, contact persons and dates.
[21] EICTA, CECED, AeA Europe and EERA Joint Position Guidance on implementing article 11 of Directive 2002/96 (EC) concerning information for treatment facilities, September 2005

ucts. Business partners are requested to follow this standard, but the standard is not accessible for WEEE-processors (Company A, 2013).

Company B and C report that information can be supplied on specific request from WEEE-processors via the producers' web pages. In that case, the producers will supply information dependent on the request and level of detail. Not all data are immediately available but have to be searched for or requested from sub-suppliers (Company B and C, 2013). Company C reports that it has had no requests for information from WEEE-processors through the last 8 years (Company C, 2013).

Company B wants to make information available, but is in doubt about which information is needed and how the company should make it accessible for WEEE-processors (Company B, 2013).

The EEE-producers do have focus on the 14 critical substances identified by the EU-Commission e.g. rare earth metals, but data on the critical resources is neither immediately accessible for WEEE-processors from any of the EEE-producers websites, nor specifically mentioned in the joint position guidance or in the global management standard that Company A uses as internal guidance. During interviews on these topics with an EEE-producer and one Danish EEE-association (BFE - The Danish Consumer Electronics Association), the lack of focus on critical resources in a WEEE-context is explained by the fact that the critical substances are still affordable as raw materials. Even though the pure raw materials are costly, this is outbalanced by the very low contents in each individual EEE-product (Company A and BFE, 2013)

Which data could you make accessible for the WEEE-processors?

Company A replies that WEEE-processors' needs of information must be specified and agreed upon at international organisational level. How information should be made available should be discussed subsequently (Company A, 2013)

All companies underline that the information to WEEE-processers must be non-confidential and an absolute necessity by the WEEE-processors. This is because composition and concentrations of substances and materials in products, parts or components in some cases are business secrets (Company A, B and C, 2013).

Company B and C have limited knowledge about substances and materials and the concentrations of these in their products. In-house production of electrical components and parts is well described whereas material data for components purchased must be obtained from sub-suppliers. Information about e.g. type of plastic, type of metal, overall metal and polymer content, presence of mercury etc. can be made accessible (Company B; Company C, 2013).

Company A, B and C also state that drawings, pictures and sketches can be made available without dimensions and tolerances. High detail levels e.g. presence of yttrium and the concentration requires further information from sub-suppliers and might even not be possible to obtain. Company C estimates that the resources required for collecting and maintaining these data will be excessive (Company C, 2013).

Company B and C state that their current information systems do not support this kind of data and must be changed to cope with new data and information requirements (Company B; Company C, 2013).

Company C is open for supplying the WEEE-processors with relevant information and states: "*In general there is a need to match the needs of the WEEE-processors with our capabilities, yet if this analysis shows huge gaps, there is a common understanding in the company that we need to work on improving the information system in order to support the end-of-life stage of the products*" (Company C, 2013).

Would it be possible to make data accessible in databases? Who should own and administer them?

Company B and C believe that data can be made available in databases with restricted access for relevant business partners to the extent data are available and with respect to confidentiality, immaterial rights etc. (Company B; Company C, 2013)

Company C suggests to provide external parties access to specific product and production data in the EEE-producers' databases via a unique identifier in a RFID-tag. An RFID-solution could contain a Uniform Resource Locator (URL) pointing to the right information. A Web Client solution would be an option here. Company C also suggests that the database should be owned and administered by the EEE-producers. (Company C, 2013).

Would you be able to RFID-tag your products sold in the EU?

Company A is reluctant to the use of RFID-technology and refers to the technical report from 2006, which was described in chapter 1. Even though the study was conducted several years ago, Company A considers the limitations described therein still to be valid and especially point to the fear of violations of consumers' privacy (Company A, 2013).

Company A also refers to a newer study [22] that also identifies privacy as one of the most important points, but also recommends that awareness is raised on the benefits of the RFID-technology (Company A, 2013).

Company B and company C believe it is possible to RFID-tag their products if they make modifications of their production set-up. Company C emphasizes that an RFID-solution should add value in processes and that the tag must be invisible in the product (Company C, 2013).

What are the barriers for using RFID as information facilitator between EEE producer and WEEE processor?

Overall, the interviewed companies point out that the aspect of confidentiality needs to be addressed. Company C suggests looking into a solution for example to have locked RFID-tags so that only waste handling facilities can read it (Company C, 2013).

Company B has assessed the suitability of RFID on going and has previously completed a pilot with Danish Technological Institute on this matter. RFID-tags are used in the internal production, but not systematically in all products. This is mainly due to different technical barriers such as lack of global standards concerning frequency ranges, lack of readability on pallets of metallic products and the cost of RFID-tags (Company B, 2013).

Company A sees a barrier in the lack of clarification and agreement on what data are imperative to inform about. It should be clarified and agreed on EU level so that an EEE-

[22] www.rand.org/pubs/technical_reports/TR1283.html

producer only needs to make one set of data available for a specific product placed on the market in the EU (Company A, 2013).

All the interviewed companies also have concerns about resource requirements in general to administer these data and specifically about resource requirements for up-dating the data in connection to product modifications. Another concern is that the companies' knowledge about substances and materials change over time. In this regard, company C states: "*Substances and materials judged to be harmless today might show up to be of concern tomorrow and we need to change the data in the database for already delivered products and then the original coding of the RFID-tag is not valid any longer*." (Company C, 2013).

Even though there are barriers for the use of RFID-tags the companies also see some opportunities. One company states: "*The Standard Unit Cost (SUC) will increase, but in the long run this will be compensated by improved traceability. But on the other hand RFID-tags allow for improved traceability and service log etc. from cradle to cradle, and consequently we can offer the user improved services that is not available for the user today*". (Company A, 2013)

4.2 Discussion

Based on the responds from the EEE-producers it seems that the fulfilment of the WEEE-processors' need for detailed standardized information on component level, easily electronically accessible information and information usable in the production environment still has some way to go.

First of all it seems that the WEEE-processors' request for data on presence of substances and materials and their content on component level is not fulfilled by the guidance agreed upon by the producer- and recycler-organizations (see Annex 4). This guidance secures information about positive presence about substances on product or product family level and is mainly focused on the hazardous substances in WEEE. It does not give information about the valuable materials in the products, which also is of interest for the WEEE-processors. So full compliance with this guidance by the EEE-producers is not enough to fulfil the request of very detailed information from the WEEE-processors.

Secondly, it also seems to be a challenge for the EEE-producers to fulfil the request for detailed content on component level since this is not knowledge which necessarily is present at the end-producer of an electrical and electronic product. The EEE-producers' ability to get the detailed information varies and depends among others on their level of control over the supply chain. It seems that the more control the easier it is to get the information or to control the substances and materials selected for design.

In addition, the WEEE-processors' requirement for immediate direct electronic accessibility of data is not met today as the data must be requested via the EEE-producers' home pages with no direct access to the data.

The EEE-producers express a wish to provide relevant and valuable data to WEEE-processors, but also express a need to have a further and more detailed clarification of what WEEE-processers exactly want to know and how this information can be provided in a meaningful way. The forum in which the common guidance-document has been developed might be a relevant forum to set more specific standards for information transfer between EEE-producers and WEEE-processors on EU-level.

In the future the EEE-producers see RFID-tags as a possible way of knowledge transfer although there are some reservations concerning confidentiality, costs, product design and the resources required to establish and develop a common system. This system needs to be updated at all times to secure relevant information for the WEEE-processors.

One suggestion for a future system is a common EEE-producer database where external parties can gain access to specific products and product-data by reading a EPC code of a RFID-tag placed on the products. This suggested solution has similarities to the data capturing process described in chapter 2. The EPC code on the RFID-tag functions as a key to find the EEE-producer, access the producers server and get the required information about materials, content, chemical structure, location etc. in the database for the specific product that the RFID-tag is placed upon. This way the information to WEEE-processors can continually be up-dated by making changes in the product-database and not by updating the specific RFID-tag.

4.3 Main points to consider concerning the use of RFID-tags

The major points to consider expressed by the EEE-producers for the use of RFID-technology as a way of exchanging information between the EEE-producer and the WEEE-processor are:

- The information provided for the WEEE-processors must be standardized as a minimum within the EU, and in this respect:
- EEE-producers need to define and agree with WEEE-processors about the content and level of detail in the information that needs to be shared
- It can be difficult for producers to provide the detailed information requirements expressed by the WEEE-processors:
    - The EEE-producers ability to get sufficient detailed information about contents substances, concentrations etc. from their suppliers can be a limitation
    - Confidentiality of product design, composition, construction etc. can be a limitation to provide the level of detail needed
- Confidentiality and privacy: only WEEE-processors should be able to access the data by using RFID and it must for instance be hindered that individual person data can be linked to specific products.
- RFID-technology must add value for both EEE-producers and WEEE-processors. At this point, the incentives today for EEE-producers to supply data seems to be weak.
- Concerns about resources need for data management and cost effects on products due to possible product modifications in order to fit and hide the RFID-tag and secure readability. But also concerns about the cost of the RFID-technology system without any added value for the EEE-producers.

5. Discussion

In this chapter a possible set-up for using RFID-technology to ensure a relevant flow of information between EEE-producers and WEEE-processors is presented and discussed. The discussion is based on the technology overview in chapter 2, input from the interviews presented in chapter 3 and 4 and is inspired by two different cases where standards for exchange of information through value chains is already established.

At first the two different cases for sharing information through value chains are presented briefly. Both systems are independent of the data acquisition technology and the data can be accessed via barcodes, RFID-technology or merely a look-up via the internet.

The first system described is the GS1 Global Data Synchronization Network (GDSN), which relates to data exchange between partners in the supply chain for Fast Moving Consumer Goods (FMCG)[23]. The second is the International Dismantling Information System (IDIS) which is a system that transfer automobile dismantling data from the automobile producers to the automobile waste handling industry.

5.1 Case 1 - GS1 Global Data Synchronization Network (GDSN)

The GS1 Global Data Synchronisation Network connects trading partners (manufacturers, retailers, distributors, hospitals, wholesalers and group purchase organisations) to the GS1 Global Registry®. This connection is made via a network of interoperable GDSN-certified data pools. In order to identify the trade items within this network the GS1 Identification Keys come into play. Their role is to support the identification of items, services, locations, logistic units, returnable containers etc. Specific to GDSN are three ID keys. These keys are used to help identify the trade items: the Global Trade Item Numbers (GTIN), the Global Location Numbers (GLN) and the Global Product Classification (GPC).

The GS1 Global Registry® is the GDSN's "information directory" that details who has subscribed to trade item or party data, guarantees the uniqueness of the registered items and parties, and ensures that all data pools in the network are complying with a standard-based set of validation rules. GS1-certified data pools are electronic catalogues of standardised item data. They serve as a source and/or a recipient of master data.

The figure below shows in simplified form the dataflow in the GDSN system. Suppliers as well as retailers are linked together via the GDSN.

[23] Fast-Moving Consumer Goods (FMCG) or Consumer Packaged Goods (CPG) are products that are sold quickly and at relatively low cost.

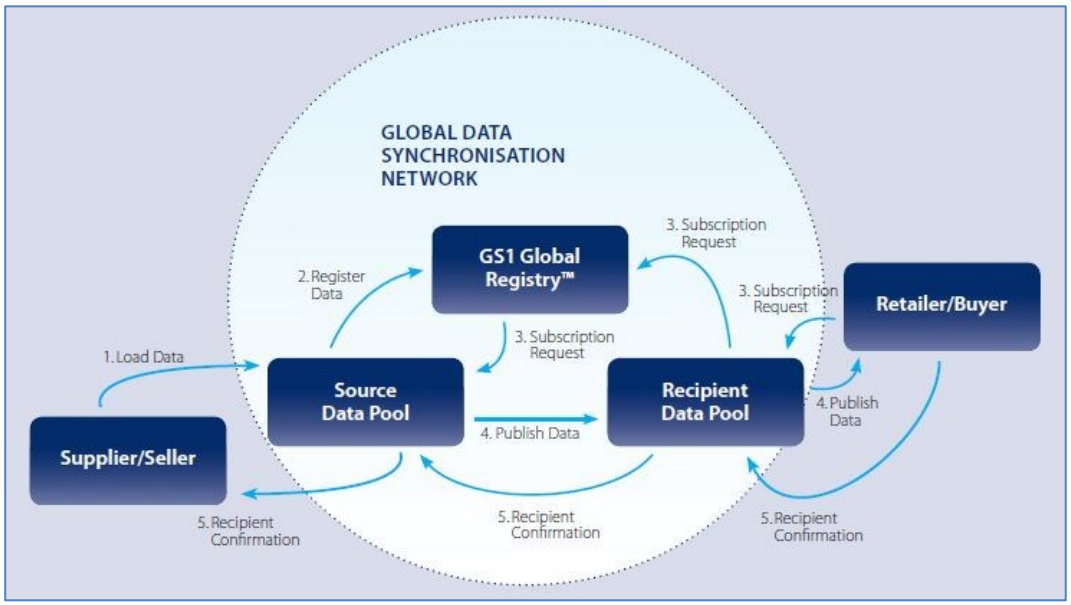

IMAGE 6
THE GDSN PROCESSES

Five simple steps allow trading partners to synchronize item, location and price data with each other:

1. **Load data:** Seller registers product and company information in its data pool.
2. **Register data:** Small subset of this data is sent to the GS1 Global Registry.
3. **Request subscription:** Buyers subscribe to receive seller's information through their own data pool.
4. **Publish data:** Seller's data pool publishes the requested information to the buyer's data pool.
5. **Confirm & inform:** Buyer sends a confirmation to the seller via each company's data pool, which informs the supplier of the action taken by the retailer using the information.

Access to the data in the data pool could be either via GS1 barcodes or via the GS1 Identification Key information integrated in a RFID-tag. The RFID-tag contains EPC Gen2[24] that is a unique number used to identify a specific item in the supply chain (see also previous description in chapter 2). No matter which access-method is chosen to the data pool it does not carry personal identifiable information.

The combination of access methods provides an environment for secure and continuous synchronization of accurate data. As a result trading partners always have the same information in their systems and any changes made to one company's database are automatically sent to all of the other companies who do business with them. The GDSN is today used with great success to exchange data in the FMCG business. For instance when Unilever shall update their data on products to the Scandinavian market, they only have to do it in one data base and all supermarket chains in Scandinavia will then have access to the updated data.

Global Data Synchronisation streamlines the labour intensive, error-prone form filling process that is currently used to share product information between suppliers and retailers and replaces it with an automated, industry-wide approach. Starting a data synchroni-

[24] Electronic Product Code Generation 2, see chapter 2

zation program is a business project and not an IT project, so it is important to get business leaders engaged. With GDSN the retailers and their suppliers will be able to share data in real time so both always have the most accurate information readily available. So when the trading partners update their product information, all partner's systems will update too. It means that retailers will be able to increase the accuracy of their orders, decrease the time to market for products, reduce the invoice errors and number of duplicate processes and thereby drive down supply chain costs.

GS1 is the international standards development organisation. The Standards Development team develops global standards using the Global Standards Management Process (GSMP). The Global Standard Management Process (GSMP) of GS1 develops the standards needed to support GDSN.

The GDSN User Group within the GS1 organisation performs standards and development of format. A number of international GDSN-certified data pools runs the databases. The implementation is constantly running and driven by the local GS1 organisations in the different countries. In Denmark for example is has taken more than 10 years to set-up the system between retailers and suppliers.

5.2 Case 2 - The International Dismantling Information System (IDIS)

The automotive industry has since year 2000 been covered by producer responsibility for cars like the producer responsibility for WEEE. This is regulated in the end-of-life vehicle directive (ELV-directive)[25] . The automotive industry has set up the global system called "The International Dismantling Information System" (IDIS) in order to supply relevant information for waste treatment of end-of-life vehicles (ELVs).

IDIS is an advanced and comprehensive online information system with pre-treatment and dismantling information for end-of-life vehicles (ELV). The purpose of the system is to make data available for the ELV-dismantling companies with the intention to do environmentally sound dismantling, simplify the recycling of end-of-life vehicles, optimize efficiency and do it safely. The automotive industry operates the system and supplies the data. Together with a large number of international car manufacturers, Volkswagen has established the IDIS database system ("International Dismantling Information System") in order to simplify the recycling of end-of-life vehicles and optimise efficiency. Since its initial launch in the early nineties by a consortium of the major European automotive manufacturers, IDIS has grown into a comprehensive database comprising essential information for treating ELV's. It provides a simple 'user friendly' interface and navigation through a multilingual system that adapts displayed content to the region of use.

The system development and improvement is supervised and controlled by the IDIS2 Consortium formed by automotive manufacturers from Europe, Japan, Malaysia, Korea and the USA, covering currently 1920 different car models and variants from 69 car brands.

The access to and the use of the system is free of charge for any commercial enterprise that handles end of life vehicles. To assure an easy and fast access to the data, all data is organised in different areas such as batteries, pyrotechnics, fuels, draining, catalysts, controlled parts to be removed, tires etc. (IDIS, 2013). The IDIS on-line information system contains safe handling information like airbag deployment instructions, information

[25] This legislation was officially adopted by the EP and Council in September 2000 and was published in Official Journal L269 on 21st October (Directive 2000/53/EC - the "ELV Directive")

about potentially recyclable parts and components, regulated in the ELV-directive (e.g. mercury and lead in batteries or electronic devices).

Below are images from the IDIS database which illustrates some of these options.

IMAGE 8
EXAMPLES OF PRESENTATIONS IN IDIS

In each of the areas a direct overview of possible parts for the specific vehicle is given. Overviews are presented in drawings, plans, photos and seems easy to use. Special safety precautions can be accessed by clicking on red dots placed in the item icons.

Access to the data and specifications are given via the internet and serves as a library of information that the user can use via lookup and the model number of the car. Presently the data cannot be accessed automatically by using barcodes, RFID-technology or other means of automated search modes.

IDIS has limited success today at least in Denmark as small recyclers do not use the IDIS system sufficiently[26]. A more specific analysis of the reasons for this is out of the scope of this report, but one reason could be that the internet access is too time consuming in the

[26] Study 2010 - End of life vehicles: Legal aspects, national practices and recommendations for future successful approach

dismantling process and that the data cannot be transferred immediately for automation and administrative purposes.

5.3 A suggestion for a RFID-system for data exchange in relation to WEEE

The challenges concerning information flow in the value chain that the two above described systems try to solve is similar to the challenges that are seen in the WEEE-context. Besides this the interviews described in chapter 3 and 4 reveal some suggestions and conditions for future exchange of information between EEE-producers and WEEE-processers which to some extend could be covered by a system that combines the two systems in the above presented cases. For instance:

- Exchange of information and data should be based on standards. It is suggested that both IEC 62474:2012 "Material declaration for products of and for the electro-technical industry" and the GS1 standards could be the backbone in future solutions.
- Access to specific product and production data in the EEE-producers' databases is suggested to be provided to external parties via a unique identifier in a RFID-tag. An RFID-solution could contain a Uniform Resource Locator (URL) pointing to the right information. It is also suggested that the database should be owned and administered by the EEE-producers. A suggestion like this would also solve the overall concerns by the EEE-producers on confidentiality and tampering with data.
- Clarification and agreement on what data are imperative to inform about is suggested to be agreed as a minimum on EU level so that an EEE-producer only needs to make one set of data available for a specific product placed on the market in the EU.

Based on the above presented existing systems for exchange of information through the value chain and the proposals from WEEE-processors and EEE-producers a suggestion to a data exchange system for WEEE is presented in the following. The cost connected to the suggested system is evaluated and barriers are discussed.

5.3.1 Set-up of a RFID-system

The set-up of a RFID-system should be based on the WEEE-handling process and the information needed here. The interviews show that right information in real time is key for the WEEE-processors. In addition, the processes in handling WEEE are in great extent automatized and the system should fit these automatized processes. In this regard the RFID-technology is superior to other technologies like barcodes, vision systems and radiation systems as this technology offers 1) a unique item based solution, 2) an automated reading without line of sight and 3) a fairly inexpensive solution as long as standardized elements are used.

One scenario for the use of RFID-tags could be the following: When the products are scrapped they typically end up in containers with many types of WEEE mixed at the municipal collection point from where the containers are collected and shipped to the WEEE-processors. A first reading of the RFID-tags could be while the WEEE is in the collection container and could give knowledge on the composition of products in the container. This knowledge could be used to allocate the contents of the container to the most appropriate handling group and in optimum order at the WEEE–processor. The RFID-tag could also at this point give relevant information to the EEE-producer for instance that a given product has become waste when is has been detected later by the WEEE-processor.

In the pre-treatment process the container is emptied on a conveyor belt and the individual products are scanned with a RFID-reader. The RFID-tag communicates the unique electronic product code when it is read. Software processes this code and via an index database the unique product code and relevant data is looked up in one or several underlying databases owned and administered by the electronic producers and communicated directly to the WEEE-processor. Now exact relevant information about the specific piece of WEEE is available in real time. The illustration below shows a model for the described scenario:

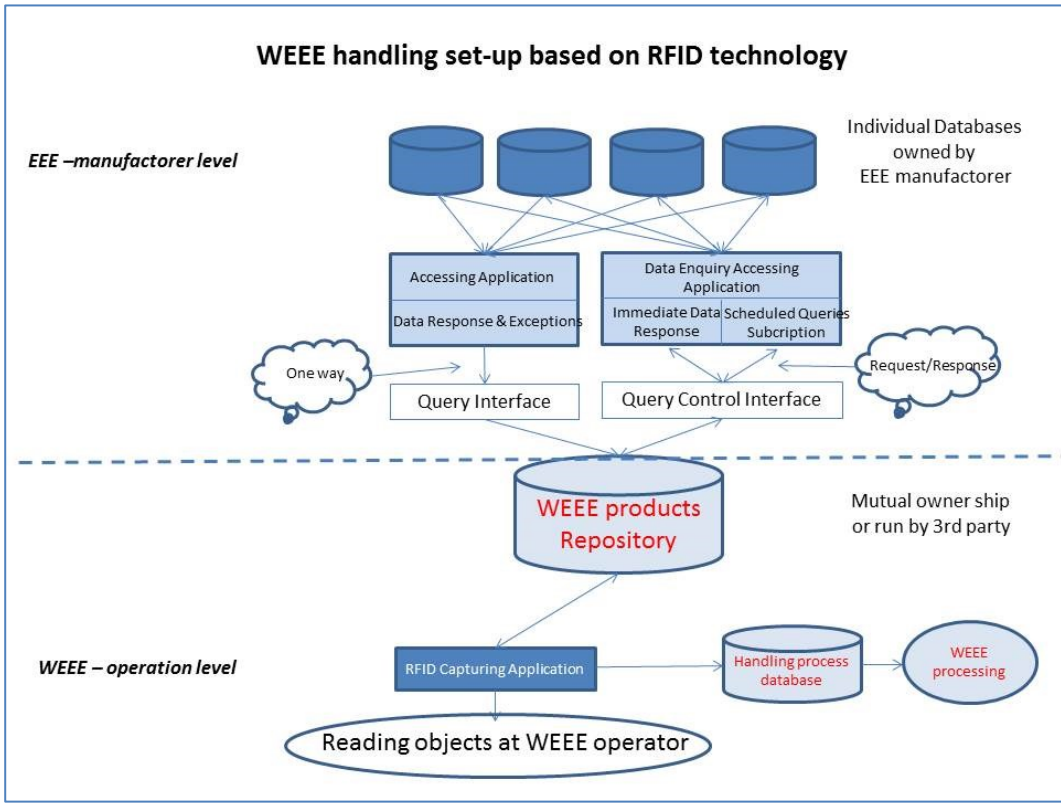

IMAGE 10
THE WEEE HANDLING SET-UP BASED ON RFID-TECHNOLOGY

The image above illustrates the suggested set-up. This image portrays that once an EEE-producer and WEEE-processor is a part of the network; they may start exchanging standardised product data with their clients via the different data pools. Thanks to these "electronic catalogues" an EEE-producer only need to publish the information once in order to diffuse it to all of their clients at the same time.

The image also illustrates the different ways a WEEE-processor can access the data, either by subscription ("*Scheduled Queries Subscription"*) or by full partner access to the database (*"Repository"*) like an open library.

By combining the set-up from the GDSN-system and using standardised digitalised data that can be accessed via the key information from the RFID-tag, it should be possible to fully automate the data query process that is needed and specified by the WEEE-processors. It will also be possible to fulfil the overall concerns by the EEE-producers on confidentiality and tampering with data through mutual agreements and protection of the different databases.

The EPC code on the RFID-tag functions as a key to find the EEE-producer, access the producers server and get the required information about materials, content, chemical structure, location etc. in the database for the specific product that the RFID-tag is placed upon. In this way the information to WEEE-processors can continually be up-dated by making changes in the product-database and not by updating the specific RFID-tag.

One or more databases should be developed containing a unique product code and relevant data organised in a suitable structure related to the knowledge needed by the WEEE-processors. The databases must be maintained typically by the EEE-producers. Access to the databases should be restricted by an adequate authorization structure.

The total system could be administered by a mutual agreed organisation or by one of the existing international standardisation organisations.

5.3.2 What tag-type?

To establish a full working RFID-technology based system for exchanging data in a WEEE handling set-up it will be necessary to RFID-tag all electrical products by the EEE-producer before marketing or initial use of the product. There are many types of RFID-tags to choose with different characteristics (see chapter 2 and annex 1).

The basic RFID-technology used for tracking and tracing in the supply chain described in case 1 uses the EPCglobal Gen 2 which is in the Ultra-High Frequency band (UHF) and can be both passive and active tags. There are some disadvantages using UHF-systems. The radio waves can bounce off surfaces and reach tags that it is not expected to be reached which means that the system can read tags that is it not supposed to be read. There are also some challenges using UHF systems around metal and water since the UHF waves are absorbed by water and liquids and waves do not penetrate metal. These disadvantages are however counterbalanced by the advantages of this type of RFID-tag. This type of RFID-tag has undergone a huge evolution during the last 10-15 years and is the most common used tag today.

Some of these challenges have either found technical or practical solutions as presented in table 4. Also the price has reduced significantly over the last 10 years and passive? tags can now be acquired for some few Euro cents (0.04-0.08 Euro) per tag depending on order volume.

Because of international deployment, standardisation and development in prices it is suggested to make use of the EPCglobal type of RFID-tag in the above suggested set-up for exchange of information between EEE-producers and WEEE-processors. Choice of active or passive tags in the suggested set-up is a matter of price.

5.3.3 Economy of the suggested RFID-system

The expenses for a full RFID-installation are very difficult to estimate. The expenses will be dependent on the actual set-up and number of places the system should work in, the number of companies using it and last but not least the organizational set-up the system should function in. Therefore a calculation on return on investment is very difficult to set up at present stage.

An idea of prices on the different elements are given below based on the present standards:

Element	Price
RFID-Tags EPCglobal Gen 2	4-8 Euro cents (0.30-0.60 DKK)/tag dependent on volume
RFID-Reader/ Antenna	2,000-5,000 Euro per unit (15,000-37,500 DKK)
Mobil RFID-Reader	250-4,000 Euro per unit (2,000-30,000 DKK)
Integration to existing systems (Changes, testing and adjustments)	+ 20,000 Euro (150,000 DKK) dependent on systems per partner/participant
Databases and implementation (Education, training, changes, testing and adjustments)	+ 40,000 Euro (300,000 DKK) dependent on size and access per partner/participant

TABLE 3
ELEMENTS OF AN RFID-INSTALLATION AND THEIR COST

These figures are not very different from other IT-systems and installations. As a whole, there are presently no standard installation kits that can be bought for installation and this of course means that a full installation only can be implemented together with some professional software houses and operators. On the top of this education of staff and employees is very important and the costs concerned with this should not be underestimated.

It is fair to expect that the technology prices will continue to decline as the use of RFID expands (tags, readers etc.)[27]. Tag prices have seen the most dramatic decrease and represent the variable cost in a designated solution. Also the deployment of RFID is not as difficult as originally thought thus reducing the integration costs. Prices have also decreased due to both technology development and organizational development taken place:

- International standards have been developed and introduced related to identifying, capturing and exchanging data in supply chain (GS1)
- RFID-reader efficiency has improved
- RFID-tag performance has been improved and more special tags are available (readability near metal and in water)

Most importantly it is today possible to read RFID-tags across borders (Europe, America, Asia) without changing tags or readers which makes it possible to have global solutions.

This adds-up to that RFID-technology based solutions have become cheaper and are expected to further decrease in price in the near future (3-5 years period).

However, the use of RFID-technology for only waste management purposes will not pay the costs for the EEE-producers. Therefore it is important to look into the suggested benefits stated by the EEE-producers during the interviews. Benefits that might pay-off in the long run for all parties. This means that RFID-tag use for WEEE management needs

[27] A.o. – Granau, Henrik RFIDsec Denmark and other, D2.1 – market analysis consumption report - RACE networkRFID - 31-08-2009 -

to be an integrated part of automatic products identification during the whole product life cycle and including all benefits in all parts of a supply chain.

A future investment and the payback on this should cover all.

5.3.4 Challenges in the suggested set-up

As described it ought to be technically possible to develop and build a RFID-technology based system to provide relevant information flow between EEE-producers and WEEE-processors. Based on experiences from similar set-ups in track-and-trace supply chain solutions a similar RFID-technology based system would also be able to function technically in a WEEE supply chain. Resent development in RFID-technology combined with the request to obtain a better utilisation of the materials in the WEEE could be the initiating factors to start a build-up of a mutual and standardized system including databases.

However, there are a number of challenges in building up a RFID-system. A full scale RFID-technology based system to manage WEEE will only have a chance if it is implemented at least on EU scale. This is because the data needs to be standardized and to follow the principles of fair competition and not include varying systems and data requirements from country to country. A system like this should be developed and administered in collaboration between many different partners across the value chain as it was seen in the development of the GSDN. A collaboration like this is not without challenges and will not happen without a great extent of collaboration and investment of both time and money from the different parties. Therefore the big issue here is not a technological issue but a question on how information can be available, organization of databases and the willingness to cooperate in a global scale on exchanging vital information for the benefit of all partners in the supply chain.

To sum up the table below gives an overview of different barriers and solutions to these in the suggested set-up:

Barriers in the system	How to solve this in proposed system
Quality and readability of the RFID-tag - defect tag, deteriorated tag, environmental wear	• Placing the RFID-tag a protected place at the product • Additional barcode and visible product-ID
Low readability of the RFID-tag on metal or in moist environment	• Special RFID-tags are developed for tagging on metal surfaces • Wet and moist environment should be avoided, but tags are developed for wet surfaces • Design and placing of RFID-tag will solve this
Confidentiality of product data such as material contents and composition, design details, critical dimensions etc.	• Protection of data by restricted access to vital information in more dimensions
Lack of uniform standardized data on EEE product level	• Agreement between producers and processors on what information is required in detail in the structure to continue development of industry standards in this area
How should the roles be in administration and using of the databases - develop, keep up-to-date	• Proposal on decentralized databases managed by the producers • Independent operator should manage the system set-up and handle electronic communication and administer development in close connection with the industry • WEEE processors should get trusted access to the data
Lack of valid and up-to date data for all products	• Easy electronic solution and access to maintain the databases • Control body for audit of the system
Incompatibility of the RFID-tag with product materials e.g. plastics	• Consciousness about compatibility in design of product and/or automation in removing the tag. • Once printed tags are available the problem is solved

RFID-tags are contributing to increased WEEE amounts.	• Consciousness about compatibility in design of product and/or automation in removing the tag. • Once printed tags are available the problem is solved
Violations of privacy – the fear that personal data can be linked to RFID-data on specific products not only in WEEE context but widely on products.	• Privacy related to personal use is important; therefore, a solution will be to decouple RFID-ID from the personal use in the WEEE processes i.e. only access to product data during EoL processing. • Reading of RFID-data is protected by access control • The data in the RFID-tag is only a number as a key to a database.

TABLE 4
BARRIERS AND SOLUTIONS TO MAKE USE OF THE SUGGESTED SET-UP OF USING OF RFID-TECHNOLOGY TO SECURE RELEVANT INFORMATION FLOW

As previously stated the workshop showed that there are varying views among WEEE-processors about whether increased transfer of information by means of the RFID-technology can have an effect on the recycling of WEEE. All participants at the workshop agreed that the main challenge would be the organization and maintenance of an international database-system.

5.4 Benefits for WEEE-processors and EEE-producers in using a RFID-technological solution

The use of a RFID-technological solution for WEEE-management only makes sense if the system is an integrated part of automatic products identification during the whole product life cycle and includes benefits for all parts of the supply chain.

Looking at the full value chain from EEE-producer to consumer/user and finally to WEEE-processor the benefits and business models by using RFID-technology differ significantly.

Benefits for the WEEE-processor are related to efficiency in processes handling the goods, units and materials, while benefits for the EEE-producer will be related to sales, marketing, customer services and recycle of materials, if they have a set-up that can handle reverse logistics and costs that may be imposed on the manufacturer.

Benefits for consumers and end-users are not dealt with in this report, but might all be related to different services in relation to EEE-producers and marketing efforts

A driver for the development of a system can be a more systematic attention to the benefits for the different actors in the value chain and the development of business cases and demonstration projects that can estimate and communicate proven opportunities and advantages for all parties. In the following list, the possible benefits for WEEE-processors and EEE-producers are presented.

Benefits - WEEE-processors:

- The possibility to detect and determine the amounts of valuable materials to recycle from a specific WEEE-product in order to achieve higher purity of the fractions and thereby increase the value of the waste.
- Be the basis for evidence-based settlement and calculations with WEEE processors and waste buyers on quality/purity of fractions and on prices.
- Detect hazardous substances and materials in WEEE, which is relevant both in order to secure compliance with regulation, but also in order to avoid contamination with hazardous substances of recyclable materials.

- Use the data for automation purposes e.g. use the RFID signal to trigger down-stream processes e.g. vision systems, actuators, X-ray etc.
- Track trends in product materials and substances and forecast future amounts and markets
- Pre-sorting of WEEE in high grade and low-grade fractions gives the opportunity to increase efficiency in the waste handling processes.
- Streamline administrative processes e.g. documentation of pre-treated WEEE, quantities, substances and materials for internal use by the WEEE-processor and for reporting to authorities like the Danish EPA or give relevant information to EEE-producers.
- With the access to more detailed information, it will be possible to build and secure more valid investment calculations for new processes capable of extracting critical resources more efficiently as well from a quantitative as from a qualitative point of view.
- Be the basis for a refund or resource premium incentive system in support for more collection of WEEE.

Benefits - EEE-producers:

- Tracking of free riders on disposal costs is eased and more companies participate in the system and existing companies will need to pay less. Depending on registration in databases of 'counterfeiters'.
- Identification of products in the waste flow containing parts and materials for reuse i.e. products or parts being reused directly in new products.
- Differentiated calculations and settlement of collective schemes e.g. based on the degree of eco-design, eco-friendly ingredients, etc. Depending on registration in databases of EEE-producers with eco-design and CSR-schemes.
- The EEE-producers could use the RFID-technology to provide customers and other actors in the total supply chain with relevant information and services during product lifetime e.g. weight and volume (relevant for shipping), tracking (relevant for warehouse/inventory), manuals, technical information, marketing materials, application information, environmental and safety guidelines, disposal instructions, etc. (relevant for service, consumer, collection site) and much more. This is possible because the RFID-tag stays on the product throughout the products entire lifetime and can be updated with new information in an on-going process.
- Supply the EEE-producer with data through the entire supply chain and finally at the end of life when collected as WEEE. The producer can benefit from this valuable business intelligence and use it for strategic, tactical and operational decisions.
- The RFID-system can provide new insights into the EEE-producers products' lifecycle and interactions in the supply chain, which can be a foundation for new business cases and more circular business models.
- Increase the possibilities of own product-take-back-systems relating to more circular business with producer ownership of the resources in the entire product chain.

6. Conclusions and recommendations for further research

The analysis in this report show that WEEE-processors are in need for detailed and updated knowledge at component level about the presence of substances and materials in order to optimize the recycling-processes of WEEE. This information is not available to the WEEE-processors today. The analysis also shows that EEE-producers are willing to supply relevant information to the WEEE-processors, but that EEE-producers have reservations concerning confidentiality of this data and their technical ability to deliver data at the detailed level that the WEEE-processors request. Further mapping of exact data requirements is needed and should be followed by discussions between the two parties about means to exchange this information.

Both WEEE-processors and EEE-producers mention RFID-technology as a promising means to achieve a high level of information exchange. Based on experience from other sectors a system using RFID-tags in a WEEE-context is briefly described in the report.

The conclusion is that it is possible to build up a RFID-technological solution based on UHF EPC Gen2 technology, which can handle the information requested by WEEE-processors and provide an efficient information flow and knowledge sharing between EEE-producers and WEEE-processors.

A full-scale RFID-technology based system to manage WEEE needs to be standardized on EU level as a minimum – preferably on a global scale. A system like this should be administered in collaboration between involved partners including an independent operator who should manage the system set-up, handle electronic communication and administer development in close connection with the industry.

The report shows that the main barriers for building a RFID-based solution is not technological but a matter of how information can be made available, agreement and organization of databases and the willingness to cooperate on a global scale on exchanging vital information for the benefit of society and partners in supply chain.

Another main barrier is the difficulty in proving the economic feasibility for a technological solution including RFID and development of databases for the sole purpose of WEEE-handling. An RFID-project will capitalize at the earliest after 5-10 years, as EEE needs to be marketed and reach its end-of-life stage before the WEEE-processing benefits can be harvested. A number of expenses can be foreseen up front and the possible advantages listed for WEEE-processors and EEE-producers are based on expected future benefits and technological gains in the long run (5-10 years) and under the assumption that more detailed knowledge to processes, components and materials will mean a higher degree of efficiency opportunities. In order to overcome this barrier it is key to develop business

cases and demonstration projects that can estimate and communicate proven opportunities and advantages for both EEE-producers and WEEE-processors.

A calculation on return on investment for a full RFID-installation is very difficult to set up at present stage, and it is recommended that a pilot project is set up to investigate a system set-up more thoroughly. It is recommended to organise pilot projects as follows:

1. Organisation of a demonstration project involving leading Danish ICT-developer (with RFID-technology knowledge) and a number of EEE-producers and WEEE-processors including research and development (R&D) partners.
2. Setting up R&D projects on:
    a. Standardized data on EEE-product level
    b. IT-infrastructure in a WEEE-database
    c. Efficiency of the WEEE-processes related to improved access to data on a more detailed level than today
    d. Overall organisation of a future WEEE system including RFID-technology
3. Forming groups of stakeholders from WEEE-processers and EEE-producers including organizations also representing international and European interests.

The pilot projects should be undertaken showing the commercial benefits of using RFID-technology for improving the logistics within the supply chain for a range of WEEE products. This should be coupled with an effective dissemination and marketing programme which will encourage companies to implement the technology. As part of a pilot project, a solution could focus only on the WEEE which has a very high value. One option is to do experiments where RFID-tags can automatically distinguish between high-grade and low-grade products from WEEE handlers. This could be set up as a regional pilot project for creating a basis for the development of knowledge and expertise in the field in order to uncover increased growth opportunities.

A pilot project could also focus on mapping what type of information actually will increase the value of the waste which the WEEE-processors handle. This research should focus not only on supply chain relationships, but also on how real-time data can affect performance in waste handling processes.

A relevant forum in which some of these pilot projects could be conducted could be the same partners that developed the guidance-document concerning information for treatment facilities described in chapter 4. The partners behind this guidance document represent both EEE-producers and WEEE-processors.

Annex 1: Review of the Current State of RFID

Contents

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 annex 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.

Radio **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[28] that is used globally.

The report and especially the recommendations are focused on examples on pilots, applications and research themes related and connected to RFID in waste management. We are in the report having a technical view on RFID but acknowledge that there are also organizational and socio-political aspects of implementing RFID in an industry or organization.

Although we recognize that these aspects are very important when implementing new technologies in industries and organizations and especially in such a fragmented industry like the waste management industry, we will not include such research examples in our report, as we are of the opinion that this is not a special RFID-technology issue but more or less an issue that will be important for any technology and in any industry.

[28] RFID: Class 1 Generation 2 UHF Air Interface Protocol Standard "Gen 2"

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 avail-able	Error correction algorithm avail-able	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 infor-mation build into tags	UHF EPCglobal GEN2 128/256 bits, others available
Readable/ access to database	Information is not readable without access to databases	Scanned infor-mation without access to a data-base	Scanned infor-mation without access to a data-base	Information auto-matically transferred	Access to information direct
Build-in 'intelli-gence'	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 stand-ards	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 pharmaceu-tical manufactur-ing 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 applica-tions. 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 off 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 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 which means 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-PASSIVE

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 im-

portant 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)

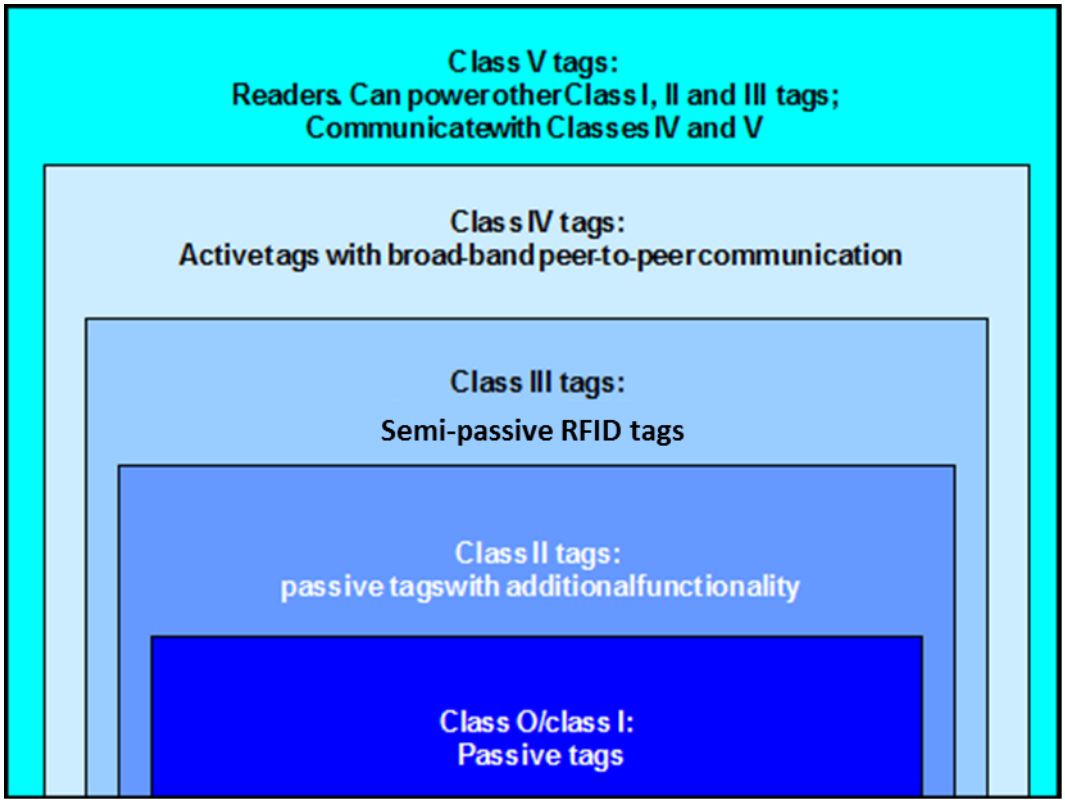

IMAGE 2
CLASSIFICATION OF TAGS

2.2.2 Passive RFID

Passive RFID-tags have no power source and no transmitter and is 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 (0 cm to 9 m 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 or 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 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 (18 m to 90 m).

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 e.g. in a distribution yard, but automakers also 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 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 0.30 meter. High frequency tags can be read from 0-0.50 meter and UHF tags can be read from 1-5 meters 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 RFID-technology	Low Frequency 125 – 135 kHz	High Frequency 13.56 MHz	Ultra High Frequency 400 – 960 MHz	Microwave 2.45 – 5.8 GHz
Availability	> 40 years	> 15 years	US > 10 years, EU > 5 years	> 15 years
Standardisation	ISO 11784/5 ISO 14223, ISO 18000-2	ISO 14443 ISO 15693, ISO 18000-3	ISO 18000-6, EPCGen1 and2 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, EU ~ 0 - 500 cm	~ 0 - 500 meters, active tags
Data transmission rate	Low	Medium	Fast	Very fast
Interference resistance	High	High Frequency	Depends on environ-ment	Susceptible to elec-tronic 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 manage-ment (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 mainte-nance
Industrial sectors	Farming, Slaughterhouse, Brewery	Airport, Slaughterhouse, Pharmaceutical, Healthcare, Production, SCM product level	Production, SCM on pallet and colli level	Army, Shipping, Airlines and Govern-ment
Other	Oct. 2004 FDA approved a 134 kHz from VeryChip that can be implanted in humans	Smart Card, Rejsekortet		
Market developers			EPCglobal, 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. 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

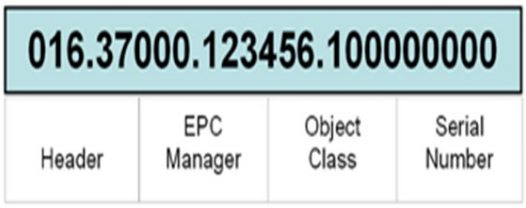

IMAGE 3
ILLUSTRATION OF AN EPC[29]

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[30]. 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 EPCglobal Network 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, 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 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. EPCglobal illustrates the data capturing process like this:

[29] www.epc-rfid.info/
[30] ThingMagic (2005) - www.rfidjournal.com/articles/view?1854 - Sep 07, 2005

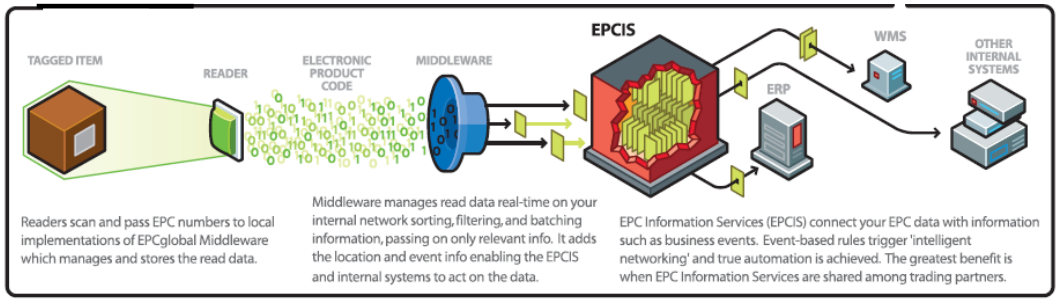

IMAGE 4
THE DATA CAPTURING PROCESS

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. Companies 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.

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[31]

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

Passive RFID-tags 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 3 to 9 m. 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 the tag does not emit a signal nor can a reader locate the tag since 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

[31] rfid.auburn.edu/media/docs/research-papers/ITRI-WP067-0306.pdf

within a 80.000 m² 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 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 3-9 metres. 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 3-9 metres, they would have to encircle your house.

Anything more than about 3 meters 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 are 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 and a unique serial number for the tagged unit (pallet, case or product). 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 – not 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. These industries are presently driving the development. Major retailers such as 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 a number of industries still 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.

The different examples mentioned in this chapter is based on many years knowledge building at the Scandinavian Auto-ID centre at the Danish Technological Institute. The knowledge is acquired through research projects, cooperation with international partners and business ventures.

3.1 Description of different sectors and applications:

A. Retail industry - Supply chain management[32]

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 were 1,000 suppliers who delivered 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. 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 reduce costs significantly 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.

[32] Source: Danish Technological Institute, Auto-ID center

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[33].

B. Food industry[34]
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 so each animal can be traced during the many processes of 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)[35]
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[36]
Early experience with RFID-tags began when the US 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. Additionally RFID is a total non-intrusive methodology for data capture (requires no human intervention), is a 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. RFID will become a key technology ena-

[33] www.2trace.com/fileadmin/PDF_Filer/ShopProtect_case_2xA4.pdf
[34] www.giotex.com/en/rfid-tags-slaughterhouse-traceability
[35] Danish Crown - www.tekno.dk/pdf/projekter/p04_RFID.pdf
[36] www.acq.osd.mil/log/sci/ait/DoD_Suppliers_Passive_RFID_Info_Guide_v15update.pdf

bler 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:

- 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)[37]
The Danish army has been one of the first movers implementing RFID. During the first Gulf 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[38]
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[39] 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[40]
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[41]. In some hospitals in

[37] the Danish Armed Forces - The Danish Defence Acquisition and Logistics Organization (DALO)
[38] www.rfidjournal.com/pharmaceutical
[39] www.fda.gov/Drugs/DrugSafety/ucm169918.htm
[40] healthcare.gaorfid.com/
[41] www.iom.edu/~/media/Files/Report%20Files/1999/To-Err-is-Human/To%20Err%20is%20Human%201999%20%20report%20brief.pdf

Western Australia[42] 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[43] or in the microwave band up to 10.6 GHz[44].

Danish implementations (cases and examples)[45]
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 situation.

F. Garments - Apparel Industry[46]
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 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 RFID-tag 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.

G. Parcel and post[47]
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.

[42] www.pcworld.idg.com.au/index.php/id;484455565;fp;2;fpid;1
[43] www.rfidjournal.com/article/view/920
[44] www.rfidjournal.com/article/view/1088
[45] www.dnu.rm.dk/bygherre/it/logistik+og+it/sporbarhed+og+emne-id
[46] www.rfidjournal.com/articles/view?3788
[47] www.rfidjournal.com/articles/view?4270

Danish implementations (cases and examples) [48].
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 all in all 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 network of readers.

H. Container tracing[49]
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 goods 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.

Danish implementations (cases and examples) [50]
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.

[48] www.rfidjournal.com/articles/view?9257
[49] www-05.ibm.com/de/automotive/downloads/rfid-container-management.pdf
[50] www.ibm.com/smarterplanet/global/files/dk__da_dk__food__container_centralen_casestory.pdf

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 RFID-tags compared to less than 90% for bar code-only tags.

In some of the biggest airports like Las Vegas[51], 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[52].

The U.S has also started to issue RFID-passports[53]. 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.

Danish implementations (cases and examples)[54]
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 system has been developed by the Danish system integrator Lyngsoe Systems, who has also been involved in many of the international airport installations.

[51] www.rfidjournal.com/article/articleprint/1949/-1/1
[52] www.rfidjournal.com/article/articleview/981/1/1/
[53] travel.state.gov/content/dam/passports/News-Articles/WHTI_final_rule_new.pdf
[54] www.lyngsoesystems.com/airport/rfid_baggage.asp

K. Cars and vehicles

In the car making industry RFID is used for different purposes. For anti-theft systems[55] 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[56] RFID-tags are used in fast lanes where the car has an active UHF RFID-tag placed in the front windshield. When the car passes the tollbooth the payment is made automatically.

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

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[57]. 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.

Danish implementations (cases and examples)[58]

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.

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 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)[59]

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.

[55] rfid.emmicroelectronic.com/webfiles/Product/RFID/AN/Wireless.pdf
[56] www.eleceng.adelaide.edu.au/personal/peter/peter/GENERAL/RFIDPix.doc
[57] www.elektroniktidningen.se/index.php?option=com_content&task=view&id=18114&Itemid=87 (Swedish)
[58] www.storebaelt.dk/english
[59] www.tagvision.dk/

M. Animal detection[60]

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. By use of a 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.

Danish implementations (cases and examples)

Denmark has also implemented ”tagging” of cows/calves. From 2010[61] each newborn livestock must have a RFID-tag in the ear, which states owner and identity. [62]

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[63].

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 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 31 million per year.

Danish implementations (cases and examples)

Berendsen Textil Service rent out work clothes to companies to be used by their employees that need specific clothing to specific persons. Berendsen Textil Service does the laundry and manages the distribution, collection, wash and redistribution back to the individ-

[60] en.nedap-livestockmanagement.com/solutions/cows-and-cow-management/dairy-management/dairy-management-identification.html
[61] www.retsinformation.dk/Forms/R0710.aspx?id=137043
[62] www.landbrugsinfo.dk/kvaeg/registrering-og-maerkning/Sider/Elektroniske-oeremaerker-banker-paa.aspx
[63] www.prosign.dk/Pigtracker.pdf - (Danish) and http://vsp.lf.dk/Publikationer/Kilder/lu_medd/2012/943.aspx

ual 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[64].

Danfoss Drives[65] 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 that Danfoss Drives produces. 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 misreading's 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 system has been implemented in the company mainly to secure a higher quality in production and increase the traceability. The company PCSYS implemented the system.

Icopal[66] 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[67]

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 which is a very laborious process to try to do manually. RFID can speed up this process considerably and simultaneously provide more reliable data.

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

[64] www.tekno.dk/pdf/projekter/p04_RFID.pdf
[65] www.pcsys.eu/BarcodesRFID/References
[66] www.icopal.dk/Produkter/Tagpap/500_serien/Minirillesystem.aspx
[67] www.rfidjournal.com/articles/view?11526

manufacturing site where it can be attached to equipment being produced, to the well-head, 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.

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)
Veriloc cooperates with the water and heating utility companies like Hovedstadens Forsyningsselskab (HOFOR) and Vestforbrænding A/S that are using RFID in different applications for asset management, maintenance and efficiency[68].

The system is used during construction work to register the received components e.g. pipes, pumps, locate their position after installation and subsequently to identify and track maintenance on these components etc. The Veriloc system consist of RFID-tags, mobile phone with GPS and an RFID reader and an App to interact with the Veriloc database. The Veriloc portal can interact with the electronic "Nemhandel"-system.

An RFID-tag is mounted on all components supplied to the project, either during production or at the suppliers 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-tag and the technical specifications is linked to the order.

When the components arrive at the construction site the handheld RFID-reader mounted on the mobile phone will scan all the RFID-tags 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 or installation. The individual components are recorded with a GPS position.

Subsequently they can be tracked very precisely in relation to the position and depth due to the precise registration during installation.

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

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.

The benefits of the this RFID-technology is traceability, reduction of administration time, risk reduction through quality assurance and the tighter control of maintenance budget. All in all increasing reliability of supplies of water and energy.

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[69]

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 utilizes RFID-based data to track the quantity and type of waste collected. The RFID-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[70] (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 is integrated into a manufacturing product database, which contains information about each tagged printer.

[69] AMCS Group, UK – www.amcsgroup.com/uk/

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

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 waste treatment. The experience from this project is that most tags are still functioning after 5-6 years.

Danish implementations (cases and examples)[71]
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[72] 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. Also 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 by 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.[73]

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

[71] pantstation.danskretursystem.dk/
[72] Suppliers: Antenna - Prosign RFID, Struer, Denmark, Labels and tags - RF-Labeltech, Randers, Denmark, Software – Grontmiij, Glostrup, Denmark
[73] www.rfidjournal.com/purchase-access?type=Article&id=10615&r=%2Farticles%2Fview%3F10615%2F3

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. And once they complete the tests, there is a full electronic record to show compliance with safety[74].

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 and every 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[75].

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 which minimize the administration of the system.[76]

Lalandia water world: Lalandia in Billund has from the beginning had 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[77]. IBM is the solution provider.

Grundfos LIFELINK[78]: 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.

[74] www.rfidjournal.com/articles/view?9322
[75] www.mediatecgroup.com/news/2013/cheerleading-at-vasaloppet
[76] www.elob.dk/Forside-1.aspx
[77] www-304.ibm.com/businesscenter/cpe/download0/175182/Lalandia_refcase.pdf
[78] www.grundfoslifelink.com/

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.

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

3.2 Overview of Danish actors within the RFID-technology

Company	Address/ e-mail/homepage	Services	Cases
RF LabelTech A/S Danish	Nyholmsvej 4 8930 Randers NØ, rfid@rf-labeltech.dk www.rf-labeltech.dk	Special designed RFID-tags	Tag producer and supplier
Lyngsoe Systems A/S Danish	Lyngsø Allé 3 9600 Aars info@lyngsoesystems.com www.lyngsoesystems.com	Software development and systems integration of logistics solutions. Systems design, installation maintaining control and track-and-trace systems. WMS and WCS. Automaton of sorting and distribution centers. Warehouse logistics and traceability	• Postal solutions Post DK, • Airport solutions in Aalborg, Hong Kong, Milan Malpensa, • and many more cases • Library solutions- Kolding, Hamburg and at least 8 others • Supply Chain solutions • Skanlog, Oticon and several others.
TagVision Danish	Tranevang 2, 3450 Allerød, info@tagvision.dk www.tagvision.dk	Specialized in RFID-solutions for libraries. Specialized in HF	More than 50 references from libraries in Denmark, Sweden, Norway, Netherlands, Belgium and England
Commotive A/S Danish	Rebild Skovhusevej 17, 9520 Skørping, info@commotive.com 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 Chr. M. Østergaards Vej 4a, 8700 Horsens, rna@munninspot.com www.muninspot.com	Concept development – tracking and tracing, theft prevention	Fritz Hansen - furniture
2Trace Danish	Høffdingsvej 20, 2500 Valby info@2trace.com www.2trace.com	Software, reading and integration in ERP systems 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 Berendsen Textile - tack and trace, inventory management
Veriloc Automations ApS Previously (Beta Technic) Danish	Veriloc Automation ApS Herlufsholmvej 37 2720 Vanløse, info@veriloc.dk verilocautomation.com	Systems for asset management for water and heating utility companies. Primarily UHF but also HF and LF	Hovedstadens forsyningsselskab (HOFOR), Vestforbrænding, Grundfos LIFELINK

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

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

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. But 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 and 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.

Looking at the possible driving forces for the waste management industry the following could be mentioned:

- Supply Chain Management and Logistics - effectiveness/efficiency
- Lean - thinking - efficiency in operations
- Tracking and tracing of components, vehicles, parcels etc.
- Inventory management and control
- Product ID - using the right component and device - quality and safety
- Precise and exact delivery control - PoD (Proof of Delivery) at job site - quality
- Track recording of certain vulnerable components - electronics etc. - quality
- Maintenance of service systems - for equipment, plant, distribution system, fire alarm system, etc.
- Deconstruction of equipment - for safety and right disposal of waste.
- Counterfeiting, fraud and theft - a well-known and rising problem

One could put the question who could be the "WalMart" for the waste management industry? The question cannot be answered here and presumably there will be many drivers across the industry.

5. Glossary - RFID

Active Tag: A type of RFID-tag that has its own power supply (battery or external power), and, when interrogated by a reader, emits its own signal. Typically, active tags have far greater read distances than passive tags, and they can be combined with sensors to provide information on the environment and condition of the item. They are also more expensive than passive tags and due to the battery have a limited life span.

Agile Reader: A generic term that refers to an RFID-reader that can read tags operating at different frequencies and/or using different methods for communicating between the reader and the tags.

Antenna: Conductive elements designed to radiate and/or receive radio energy. As part of an RFID-system, antennas radiate or receive radio energy to/from the RFID-tags and the reader.

Anti-collision: A general term encompassing the means of preventing radio waves from one device from interfering with radio waves from another. Anti-collision algorithms enable readers to read more than one tag in the same reader's field.

Auto-ID Center: The private/academic consortium founded in 1999 in conjunction with the Massachusetts institute of Technology. Through the support and cooperation of major manufacturers, retailers, and the U.S. government, the Auto-ID Center conducted much of the foundational research on commercializing RFID-technology and invented the concept of the Electronic Product Code. The Auto-ID Center consortium became EPCglobal in 2003.

Automatic Identification (auto-ID): A broad term encompassing technologies used to help machines identify objects. A host of technologies fall under the Automatic identification umbrella, including bar codes, biometrics, smart cards, voice recognition, and RFID.

Backscatter: A method of communication between passive RFID-tags and readers. RFID-tags using backscatter technology reflect back to the reader radio waves from the source, usually at the same carrier frequency. The reflected signal is modulated to transmit data.

Capacity: The number of bits or bytes that can be programmed into a tag. A tag's capacity may rep
resent the bits accessible to the user or the total number, including those reserved to the manufacturer (e.g., for parity or control bits).

Electronic Article Surveillance (EAS): Acknowledged by many as the first RFID-technology widely used in the retail environment and in libraries, these systems use microwave or inductive technology "readers" to detect the presence or absence of EAS tags as a means of detecting and deterring theft. When an item is purchased (or borrowed from a library), the tag is turned off. However, when someone passes a gate area holding an item with an EAS tag that hasn't been turned off, an alarm sounds. These tags are inexpensive and do not contain any data.

Electronic Product Code (EPC): A unique number, stored in the chip on an RFID-tag, which identifies an item in the supply chain, allowing for tracking of that item.

Electrostatic Coupling: systems that transfer data or power by inducing electrical voltage on a plate.

EPCglobal: The non-profit organisation that manages standards and numbering schemes associated with the EPC (Electronic Product Code). it is the successor organisation to the Auto-ID Center. EPCglobal is a subsidiary of the Uniform Code Council and EAN International now changed name to GS1, the leading retail bar-code-standards organisations. EPCglobal's membership

includes leading retailers, manufacturers, and governments from around the world.

European Article Numbering (EAN): The bar code standard used throughout Europe, Asia, and south America, and administered by EAN international. See also GTIN.

Factory Programming: The process of having an identification number written into the read-only microchip of an RFID-tag at the time the chip is made.

Field Programming: Tags that use EEPRom
(Electrically Erasable Programmable Read-only memory), or non-volatile memory, which can be programmed after being shipped from the factory.

Frequency: The number of repetitions of a complete wave within one second. For example, 1Hz equals one complete waveform in one second; 1KHz equals 1,000 waves in a second. RFID-tags use low, high, ultra-high, and microwave frequencies. All frequencies have their own advantages and disadvantages that make them more suitable for some applications than for others.

Frequency Hopping: The protocol used to prevent readers from interfering with one another in their operations by using varying frequencies. In the U.S., even though UHF RFID-readers are said to operate at 915 mHz, they actually can operate between 902 and 928 mHz. To avoid conflict with readers operating adjacently, a reader must "frequency hop"—jumping randomly or in a programmed sequence to any frequency between 902 mHz and 928 mHz. If the available band is wide enough, the chances of two readers operating at exactly the same frequency is therefore small. However, as the UHF bands in Europe and Japan are much smaller than those available in the U.S., the frequency hopping technique is not nearly as effective for preventing reader interference.

GDSN: Global Data Synchronization Network - created by the European Article Numbering association, the Uniform Code Council (EAN, UCC - now called GS1) and industry leaders worldwide, the GDSN is a network of interoperable data pools that connect to Global Registry.

GS1: GS1 is a leading global organisation dedicated to the design and implementation of global standards and solutions to improve the efficiency and visibility of supply and demand chains globally and across sectors. This is a merger between the former EAN International and former Uniform Code Council (UCC). The GS1 system of standards is the most widely used supply chain standards system in the world.

GTIN: Global Trade Identification Number - the new term for EAN number and UPC number - bar-code that used for product identification.

Harvesting: The method by which passive tags gather energy from an RFID-reader's antenna to be able to respond to the reader.

Inductive Coupling: systems that transfer data or power by inducing electromagnetic current in a coil.

Interrogator: Another name for an RFID-reader.

Memory: The amount of data that can be stored on the microchip in an RFID-tag.

Nominal Range: The range at which systems can assure reliable operation, considering normal variability of the environment in which it is expected to be used.

Passive Tag: A type of RFID-tag that does not have its own power supply. Instead, the tag draws power from the reader, which sends out electromagnetic waves that induce a current in the tag's antenna. Without an on board power source, passive tags have a lesser read range than active tags. However, they cost less than active tags and have a theoretical unlimited life span.

Phantom Read (also called a "phantom transaction" or a "false read"): The result of an RFID-reader inaccurately reporting the presence of an RFID-tag that does not exist.

Power Level: The amount of radio frequency (RF) energy radiated from a reader or an active tag. Higher-power outputs enable longer read ranges. However, most governments regulate the power levels at which RFID-readers can operate to avoid interference with other RF devices.

Programming a Tag (also called "commissioning a tag"): in the context of RFID, the process of adding identification data to or altering the data in an RFID-tag.

Radio Frequency Identification: An automatic identification technology that uses radio waves to identify objects.
Read: The process of retrieving data stored on an RFID-tag by sending electromagnetic waves to the tag and converting the radio waves the tag sends back into data.
Read Rate: The number of tags that can be read by an RFID-reader in a given time period.
Read/Write: The ability of an RFID-system to change the data that is stored in a tag. For example, as a product moves from the final packaging area to the warehouse, a read/write tag can be modified to reflect the new location, so that now, when interrogated, it passes the new location as part of its updated data stream.
Reader (also called an interrogator): A device that communicates with RFID-tags. The reader has one or more antennas, which emit radio waves and receive signals back from the tag. Readers may have a digital display to relay information to the operator and may transmit data on to an organisation's computer network infrastructure. Readers can be either fixed or portable, and today they are beginning to be integrated into other electronic devices, such as PDAs (personal digital assistants) and cell phones, and even into objects such as pens.
Reader Field: The area of coverage for an RFID-reader. if a tag is within the reader field, it can (should) receive the reader's radio wave and be read.
RFID: The acronym for Radio Frequency identification.
Semi-passive tag (also called battery-assisted tags):
A type of tag similar to an active tag in that there is an on board battery. The battery is used to run the microchip's circuitry and to boost the effective read range of the tag. some semi-passive tags sleep until they are woken up by a signal from the reader, which conserves battery life, while some are programmed to broadcast at set intervals of time.

Sensor: A device that responds to a physical stimulus and produces an electronic signal reporting on that stimulus. Sensors can be tailored to report on a variety of environmental conditions, including temperature, humidity and vibration. **Signal Attenuation:** The weakening of radio frequency (RF) energy from an RFID-tag or reader.
Slap and Ship: The practice by a manufacturer of placing RFID-tags on cases and/or pallets at the last possible point before shipping from a supplier to a mandating retailer or other organization. With a slap and ship strategy, a manufacturer or distributor is simply trying to meet the requirements of another firm's RFID mandate, rather than attempting to capture any data—and value—from RFID tagging in its own system.
Smart Label: A generic term referring to a printed label that typically contains printed information, a bar-code identifier, and an RFID-tag. The label is considered to be "smart" because of its ability to communicate with an RFID-reader.
Time Division Multiple Access (TDMA): A method used to solve the problem of signals from two readers overlapping and colliding. TDMA algorithms enable the readers to attempt to read tags at different times.
Transceiver: A device that can both transmit and receive radio waves.
Uniform Code Council (UCC): The non - profit organisation that oversees the Universal Product
Code (UPC), the bar-code standard used in North America. See also GS1.
Universal Product Code (UPC): The bar-code standard used in North America and administered by the Uniform Code Council (UCC). See also GTIN.

Annex 2: Questions for Waste Processors

The Danish Technological Institute would like to visit you in one of your electronic waste processing facilities in order to see and understand your present WEEE management processes and we would in this context discuss below questions in relation to WEEE and transfer of information from EEE producers to WEEE processers by means of RFID-technology.

- What information does the company require in order to optimize the electronic waste processing and increase reuse?
- Does the company have an idea of how this knowledge can be made optimally accessible and useable to the company's waste management process?

  - In which form must the required information be available?
  - Access to information where and how often?
  - Which technical solutions for knowledge transfer could be possible?

- Can the RFID-technology supply the knowledge, which is required in the waste process and in a way which is compatible with the waste management process?
- Which expenses, do you estimate will be related to the use of RFID-technology to ensure information flow?
- Which advantages and disadvantages, including economic, will the use of RFID-technology to ensure information flow have for you as WEEE processors?
- Which barriers do you see to realize the use of the RIFD-technology to ensure relevant information flow, and how can these be overcome?

Annex 3: Questions for Electronic Producers

May 7, 2013

The potential of the RFID-technology for information flow between electronics manufactures and waste processors

The project is a preliminary study in RFID in WEEE connection and is initiated by the Danish Environmental Protection Agency. It will constitute the basis for a further study within the RFID area. The project is estimated to be completed by the end of May 2013.

Background and purpose

An element in increasing the level and quality of reuse of electronic waste (WEEE) is to establish an information flow between electronics manufactures and waste processors. The information could e.g. concern the placement of critical resources and dangerous substances in the products, or instructions in how the products can be separated into reusable factions in connection with preprocessing the waste. It is estimated, that this information flow from manufactures to waste processors is very limited today. A challenge in this context is, among others, to find a system for the information flow, which is compatible with the way the waste management process is carried out. Several operators point to the use of RFID-tags, as a possible future solution to implement such an information flow.

The purpose of this project is to undertake a screening of the RFID-technology in order to uncover the technology potential to contribute to ensuring a relevant information flow between manufacturers and waste processors.

The Danish Technological Institute has interviewed two Danish waste processors who emphasize the need for information about:

1. Which substances/materials (e.g. yttrium) the product is made of?
2. Which amounts/concentrations (mg/kg) in the different parts?
3. Chemical form – crystalline, gas, fluids etc. does the present substances have?
4. Placement of the substances e.g. printed circuit board, cabinet, pointed out on exploded view of product etc.?

In some cases it is possible to find information about content on the manufacturers websides; but very few manufacturers specify content on a sufficient level of detail.

By having detailed knowledge of the substances and materials on the" inbound side" it is possible to optimize the recovery and it is possible to calculate the economics of the new processes, needed for extracting critical resources.

Outline of a possible system/structure

If there is going to be established a flow of information by means of RFID-tag, it will be necessary at first to RFID mark all electrical products with passive UHF-tags performed by the manufacturer before marketing or initial use of the product.

One or more databases should be developed containing a unique product code and relevant data organized in a suitable structure related to the knowledge need of the waste processors. The database must be maintained. Access to the databases should be restricted by an adequate authorization structure.

When the products are scrapped they typically end up with many types of WEEE mixed in containers at the municipal recycling station, from where the containers are collected and shipped to the WEEE processor. WEEE can also be sent from companies directly to the WEEE processor.

One possible solution could be a first reading of the RFID-tags on the WEEE products while in the container in order to get knowledge about the composition of products in the container. This knowledge could be used to allocate the contents of the container to the most appropriate handling group and in optimum order at the WEEE processor.

In order to carry out the initial treatment of the electronic waste, the container is emptied out on a conveyor belt, where the individual products are scanned with a, put up for the purpose, RFID-scanning unit. The RFID-tag communicates a unique product code when it is scanned. Software processes the code and via an index database the unique product code and relevant data is sought out in one or several underlying databases and communicated directly to the WEEE waste processor. Now exact relevant information about the specific piece of WEEE just scanned is available in real time.

The outlined solution has parallels in other trades. The car industry was in year 2000 covered by producers responsibility for cars. The car industry uses the global system ”The International Dismantling Information System” (IDIS). In the retail sector they have in order of streamlining the trade, for many years, worked with “The Global Data Synchronization Network” (GDSN).

Questions for you as manufacturers

- What information are you today making available for waste processors in relation to WEEE?
- How is this information available – which degree of details, in which form – on web sites or others? Is this data directly accessible for the waste processors or must they be requested or commissioned?
- Which data could you make accessible for the waste processors?
    - Would it be possible to inform the waste processors about: - if not- why?
        - Which substances/materials (e.g. yttrium) the product is made of.
        - Which amounts/concentrations (mg/kg) in the different parts?
        - Which chemical form – crystalline, gas, fluids etc. - do the present substances have.
        - Where are the parts with the substances placed in the product – e.g. on printed circuit board, on cabinet, preferably illustrated on ”exploded view” product drawing.
        - How to dismantle the WEEE product.
- Would you be able to make data accessible in one or more databases?
- Who should own the database/databases?
- Who should in your opinion administer the database/databases?
- Would you be able to RFID-tag you products sold in the EU?
- Which barriers are there for using RFID as information facilitator between electronic manufacturers and waste processors?
- Which economic consequences do you see with the use of RFID?

- Which opportunities do you see?
- Have you considered RFID in other applications?

We hope that you will take the time to answer these questions. It is an important input for the continued work with the RFID-technology's potential for information flow between electronic manufacturers and waste processors.

Annex 4: EICTA, CECED and EERA Joint Position Guidance

September 26, 2005

EICTA, CECED and EERA Joint Position
Guidance on implementing article 11 of Directive 2002/96 (EC) concerning information for treatment facilities

EICTA (European Information & Communications Technology Industry Association), CECED (European Committee of Domestic Equipment Manufacturers) and EERA (European Electronics Recyclers Association), have developed a common understanding of information needs on equipment characteristics relevant for end of life treatment. Consequently, the above mentioned associations hereby jointly propose a guidance in implementing Article 11 of the Directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE) (hereinafter called "the Directive").

In general terms, EICTA, CECED and EERA have established the conditions for a sustained dialogue between producers and recyclers based on agreed items of interest for a better handling of WEEE.

Each producer creates an access point for recyclers to post questions in relation to his products, typically an alias to be used on the producer's internet site
A producer, upon request from a recycler dealing with one of his equipment put on the market after August 13th 2005, provides information on "positive presence" of materials and components as listed in Annex A, at product level or product family level. Other questions will be handled on a "reasonable effort" mode. The common dialogue language is English.
Producers and recyclers contribute via above-mentioned associations to a constructive and sustained dialogue to discuss past and future technology trends used in products and update Annex A as appropriate in particular in the light of Annex 2 implementation guidance and changes.

The format the product information will take is left to the initiative of the producer. Sketches or pictures would ease the interpretation of the responses.

Depending on the solutions put in place in the different countries by producers to organize collection and treatment of their products, producers, as an alternative to the above, may look at the possibility to organise dialogue between producers and treatment operators via the take-back schemes.

Note: some of the materials and components listed in the Annex A (e.g. asbestos and capacitors containing PCB) are restricted in use in electrical and electronic equipment of abovementioned associations' member companies and are thus no longer in many products put on the market today. However, for certain applications and/or for certain sectors covered by the Directive these materials may still be used.

Annex A

Producer:	<company name, other on addressing the producer>
Scope of information sheet:	< product category as in Annex IA of WEEE Directive, or type of equipment as in Annex 1B of WEEE Directive, or producer's Product Family, or single products identified by brand and model name>

Component or Material	Remarks / Location
Battery (internal *) containing Mercury (Hg)/ NiCad/Lithium/Other	⬇
Backlighting lamps of LCD/TFT or similar screens containing Mercury (Hg)	
Mercury (Hg) in other applications**	⬇
Cadmium**	
Gas discharge lamps	
Plastic containing brominated flame retardants other than in Printed Circuit Assemblies ***	
Liquid Crystal Displays with a surface greater than 100 cm2	
Capacitors with PCB's	⬇
Capacitors with substances of concern**** + height > 25 mm, diameter > 25 mm or proportionately similar volume	⬇
Asbestos	
Refractory ceramic fibres	
Radio-active substances	
Beryllium Oxide	⬇
Other forms of Beryllium	
Gasses - which fall under Regulation (EC) 2037/2000 and all hydrocarbons (HC).	<type of gas, properties, volume and/or weight> ⬇
Components with pressurised gas which need special attention (Pressure > 1,5 bar) *****	<type of gas, pressure level, discharge method> ⬇
Liquids ***** if volume > 10 cl (or equivalence in weight, e.g. for PCB, oil...)	<type of liquid, discharge method> ⬇
Mechanical components that store mechanical energy (i.e. springs) or equivalent parts which need special attention ***** (diameter > 10 mm and height > 25 mm or proportionally similar volume and expanding)	⬇

⬇ = arrow indicates the need for the location of the compartment/ substances within the product. When the location of a substance/ components is requested, it is at part level, e.g. main board, housing etc.

* Internal means that batteries can only be removed by opening the product by means of (a) tool(s).

** Substances are considered to be in the product if present above the levels specified in Commission Decision 2005/618/EC related to Directive 2002/95/(EC) (RoHS Directive) or if their use is permitted through exemptions in the Annex of Directive 2002/95(EC)

*** To be coherent with industry current standards and practices on tracking of plastic parts, Directive 2002/96 (EC) Annex II requirement is understood to focus on plastic parts that weight more than 25 g.

**** Substance of concern other than PCB, to be specified/ addressed further in the context of Directive 2002/96 (EC) Annex II national requirements and European developments

***** Needs of equivalent nature as those for maintenance, service manuals and installation for safety purposes.

EICTA - founded in 1999 is the voice of the Information and Communications Technology and Consumer Electronics Industry in Europe. It is composed of 50 major multinational companies and 32 national associations from 24 European countries. In all, EICTA represents more than 10,000 companies all over Europe with more than 2 million employees and over EUR 200 billion in revenues.

CECED - represents the household appliances manufacturing industry in Europe. Its member companies employ over 200.000, are mainly based in Europe and have a turnover about 40 billion euro. If upstream and downstream business are taken together, the sector employs over 500.000 people.

EERA - The European Electronics Recyclers Association - EERA is a non-profit organisation that promotes the interest of recycling companies who are treating waste electrical and electronic equipment (WEEE) in Europe. EERA aims for the harmonization of national and international regulations for WEEE recycling in order to obtain a free market for demand and supply of services.
EERA calls for environmentally sound operating practices for WEEE recycling activities and members are signatories to the rules of conduct to safeguard protection of human health and the environment

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The potential of RFID-technology to secure information flow be-tween producers of electronics and waste processors

A solution to increase the degree and quality of the recycling of waste of electric and electronical equipment (WEEE) is to establish an improved information flow about content of valuable recyclable materials between producers of electronics and the recyclers. The report analyzes how the RFID-technology can provide an improved flow of information between these actors. The report also gives insight into RFID-technology, the present technology state and different examples of the use of the RFID-technology in different sectors including the waste sector.

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