IPS '01 総説

Sustainable chemistry - from theory to practice

Dolf GIELEN and Yuichi MORIGUCHI

The Japanese petrochemical industry is one of the largest in the world. The strong growth of the plastic packaging market has been fuelled by the consumer demand for clean, easy, functional and cheap products. However this success has created a number of environmental problems such as waste. CO_2 emissions and energy consumption throughout the life cycle of petrochemicals. In order to enhance the sustainability it is important to reduce these environmental impacts. The potentials for sustainable development is analysed from a technical perspective and from an economic perspective, using a set of linear programming models. The effectiveness and efficiency of policy instruments such as recycling ordinances, taxes and subsidies is compared. The model results suggest that a CO_2 tax would result in significant secondary waste benefits, and a materials tax would result in significant secondary CO_2 benefits. However the actual welfare effect of both approaches is subject to large uncertainties.

Introduction

Sustainability is defined as a resource consumption that maximizes the welfare of the living people without compromising the welfare of future generations. Packaging materials contribute significantly to the welfare of people. However life cycle studies (e. g. SAEFL 1998) indicate a number of environmental problems in relation to packaging :

- Wasteland filling:
- GHG emissions;
- Consumption of scarce resources.

Consideration of these environmental problems may affect the optimal packaging system choice. Packaging materials constitute at this moment approximately 3.3% of the total GHG emission and 14% of the material related greenhouse gas (GHG) emissions in Western Europe (Hekkert 2000). Table 1 provides an overview of Japanese packaging materials and the related environmental impacts. The figures suggest that the Japanese situation is quite similar. Plastics constitute the most problematic packaging materials category from an environmental point of view. As a consequence a discussion of sustainable packaging is largely a discussion of sustainable plastics (and sustainable chemistry).

National Institute for Environmental Studies, Tsukuba dolf.gielen@nies.go.jp

Table 1 Materials consumption for packaging 1999(Japan Packaging Institute 2001, Sakamuraetal 2001)

		CO_2 [*1]	CO_2	Waste [*2]
	[Mt/yr]	[t/t]	[Mt/yr]	[Mt/yr]
Plastics	3.5	5/0.5	15.8	-
Paper and board	13.2	0.6/0.6	7.9	-
Wood	1.1	0.5/0.5	0.6	-
Glass	1.9	0.5/0.3	1.0	0.7
Steel(est.)	2.3	2.5/0.7	4.7	0.6
Aluminum(cans)	0.3	13/2	1.3	0.1
Aluminum(foils,caps etc.)(est.)	0.1	13/2	1.3	0.1
			33.7	1.6

*1 Figures refer to primary production and recycling, respectively. Excluding credits for energy recovery
*2 Assumption 100% incineration

In many countries packaging waste is considered an important environmental problem. This has resulted in very rigid regulatory policy approaches, based on recycling targets and disposal bans and the like. The scientific basis for the environmental benefits of changes in waste management is weak. Often a generic guideline of declining waste management preferences is applied :

- Reduction;
- Re-use;
- Re-cycling ;
- Energy recovery ;
- Disposal.

Policy makers try to change the direction of waste flows through regulation. For example the German packaging ordinance is based on recycling targets, a regulatory approach. This approach has gradually spread over Europe. Japanese policy trends follow European regulatory approaches. However such regulations are not based on a life cycle optimisation perspective. This paper will discuss some alternative approaches based on the use of pricing instruments, with emphasis on sustainable chemistry. For a more detailed discussion see (Gielen and Yagita 2001, Gielen and Moriguchi 2001).

Plastics are produced from oil feedstocks. Part of the feedstock carbon is stored in products but eventually this carbon is converted into CO2 in case the products are incinerated. In order to enhance the sustainability fossil carbon must be substituted by renewable carbon (less fossil carbon for the same services), or the efficiency of fossil carbon use must be increased (more services with the same amount of fossil carbon). This can be achieved via increased efficiency of product use or via recycling and/or energy recovery. Five emission reduction strategies can be discerned:

- Substitute for the petrochemical oil feedstock ;
- Substitute for synthetic organic materials ;
- Increase the efficiency of synthetic organic materials use ;
- Recycle waste materials ;
- Recover energy from waste materials.

Materials substitution (e. g. use of cardboard packaging instead of plastic bottles) will not be discussed in more detail. Earlier analyses have indicated that the environmental benefits are questionable because of the efficiency improvement potentials that exist for all materials exceed the difference in environmental performance for individual materials, see e. g. (Gielen and Pieters 1999).

Biomass (plant and animal derived carbon) is the only renewable carbon source. Currently, biomass feedstocks constitute the basis for what is often called oleochemistry. A significant portion of the surfactants and detergents currently in use are derived from natural organic oils such as palm kernel oil. Biomass can substitute for petrochemical oil feedstocks. Although widely used for many things, biomass is not a significant feedstock for synthetic organic products. In fact, it currently represents less than 5% of the total feedstocks used for these organic products. The main reason for the limited use of biomass is its high cost compared to oil products. However a number of analyses are optimistic about a biomass feedstock strategy (see e. g. National Research Council 2000, Gielen et al. 2001).

Biomass can enter the system at three levels :

- As a feedstock for existing petrochemical basic chemicals from steam cracking, such as the use of bio-ethanol or bio-methanol for the production of ethylene ;
- As a feedstock for intermediate chemicals, such as phenol and various solvents ;
- As a biopolymer, which substitutes for polymers such as polyethylene (for example polylactic acid).

Japanese biomass strategies are limited by the country's high population density and the inaccessibility of the mountain areas, which limits the possibilities for producing large quantities of biomass at acceptable prices. The national biomass surplus amounts to 2 EJ per year (about 8% of the total primary energy use) (Fujino et al. 1999). As a consequence, import strategies deserve special attention. Many studies suggest that global long-term biomass availability may amount to 100-400 EJ/yr. Biomass feedstocks are not competitive on the short term but on the longer term declining oil reserves and increasing environmental concerns may change this situation.

Packaging services are growing rapidly, but there is ample room for improved management of materials, such as materials substitution, increased material recycling, and product reuse. Results for Western Europe (Hekkert 2000) indicate for the year 2030 a cost effective GHG reduction potential of 25% compared to the model run where the current goals of the European Packaging Directive (EPD) are simulated. This suggests a very significant no-regret potential for emission reduction in the packaging chain, based on increased materials efficiency. In case a GHG emission reduction penalty of 10,000 Y/ton CO_2 is introduced a GHG reduction of45% is achieved compared to the EPD scenario. Improvement potentials in Japan may be of a similar magnitude, given the less stringent environmental policies in the past and similar materials prices. In conclusion more attention should be paid to material efficiency improvement instead of recycling or feedstock substitution.

Plastic waste recycling can be divided into three categories :

- Back-to polymer recycling (BTP) ;
- Back-to-monomer recycling (BTM) ;
- Back-to-feedstock recycling (BTF) ;
- Enhanced energy recovery.

A lot of emphasis is put on recycling as a strategy to reduce plastic waste (PWMI 1999). Re-extrusion technology (BTP) is the most widely applied recycling technology in Japan (PWMI 2000). Mixed plastic waste can be hydrogenated to produce feedstocks such as a naphtha-like product and a hydrogenation residue that can be used in coke production (BTF). The technology can be characterized as a thermal hydrocracking/hydrogenation process. Plastic waste can be injected into blast furnaces as a substitute for coke and coal. An interesting new idea is plastic waste conversion in coke ovens. The burning process in the production of cement clinker offers multiple options for the utilization of an alternative raw material and fuel due to high temperature technical processing and the basic chemical environment (Cembureau 1999). Both cement kilns and steel plants have sufficient capacity to treat the bulk of Japanese plastic waste.

Table 2 provides an overview of the technological potential of different emission reduction options (accuracy +/－ 25%). The sum of the emission reduction potential options is well above 100 Mt CO_2 2020 (compared to a total national greenhouse gas emission of approximately 1250 Mt CO_2 equivalents). However, such an addition is misleading because of interactions of

Table 2 Japanese potential for CO_2 emission reduction in the life cycle of petrochemicals in 2020, based on static analysis(Gielen and Yagita2001, Gielen and Moriguchi 2001)

Strategy	Application	CO_2 impact [tCO_2/t]	CO_2 emission reduction potential [Mt CO_2/year]
Biomass feedstocks	Ethylene production	8	56
	Butadiene production	4	8
			25
Waste recycling	Refineries	0.9	4.5
	Blast furnaces/coke ovens	3.3	16.5
	Cement kilns	3.8	19
	Electricity production	1.4	7

emission mitigation potentials. For example a switch to biomass feedstocks will reduce the emission reduction potential of materials efficiency improvements. Moreover, cost issues and other practical constraints are not considered in table 2. These issues will be elaborated in the model analysis below.

Modelling approach

REAP 1 (Regional Environmental Assessment Program) is a techno-economic linear programming model that covers the full life cycle of all petrochemical products (see figure 1) (Gielen and Moriguchi 2001). This allows a proper comparison of options such as industrial energy efficiency improvements and biomass feedstocks vs. plastic waste recycling and increased efficiency of materials use. The relation between current materials consumption and future waste release is considered in the model.

The life cycle of petrochemicals is modelled from ' cradle to grave '. Both heat and electricity production (and the related CO_2 effects) are included in the model. The main model features are listed in table 3. 50 different types of materials are covered. Such a broad scope is important because of interactions such as co-production (e. g. in the case of naphtha steam-cracking) and energy system integration (e. g. waste heat reuse).

Five pricing policies and four types of regulation have been analysed (see table 4 for acronyms). The pricing policy scenarios assume either a tax on emissions (a conventional environmental policy approach), a tax on materials consumption or a subsidy on recycling (both examples of materials policies). Also combinations of both approaches have been analysed. The emission tax is simulated with a CO_2 penalty starting in 2005 at 2,500 Y/t, increasing to 10,000 Y/t CO_2 in 2020 and stabilising afterwards. The materials tax is modelled by a penalty of50,000 Y/t virgin

Table 3 SummaryofREAP1 model characteristics

Method	Linear programming
Objective function	Consumer/producer surplus (welfare maximisation)
Driving force	Materials service demand
Coverage	Full life cycle
Regional scope	Japan
Time period	1965-2040, 5 year periods
Coverage	All petrochemical products
Strategies considered	Fuel/feedstock switch, energy efficiency, demand reductions. recycling, energy recovery
Number of energy and material flows	90
Number of processes	150

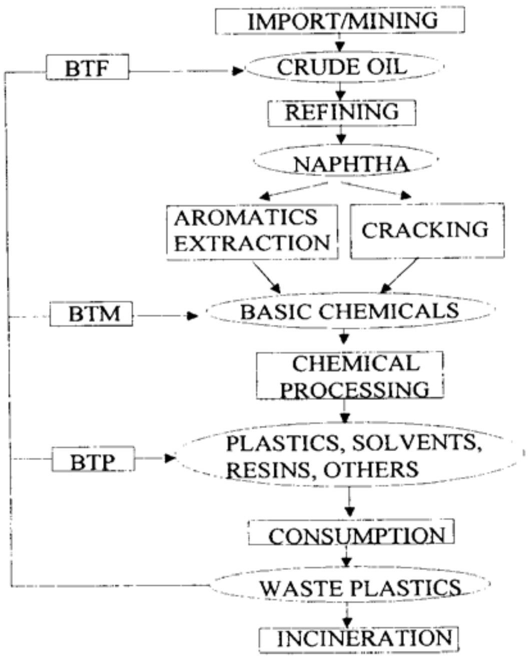


Fig. 1 Life cycle model structure in REAP1. BTF = Back to feedstock ; BTM = Back to monomer ; BTP = Back to polymer.

material. The recycling subsidy is modelled by a subsidy of 50,000 y/t recycled plastic waste. Recycling includes re-extrusion, gasification , pyrolysis , hydrogenation and plastic waste injection into blast furnaces.

Regulations have been simulated by a combination of minimum recycling rates and caps on industrial emissions. 25% , 50% and 75% recycling targets have been studied in combination with industrial emission caps of 80,60 and 40 Mt per year (from 2015 onward), respectively. Moreover a combined regulation and pricing policy has been analysed. This combined policy is based on an industrial CO_2 emissions cap of80 Mt per year and a CO_2 tax on emissions in the waste sector. Such a combination reflects current policies. Also a 25% and 50% emission reduction in both sectors has been analysed, see (Gielen and Moriguchi 2001) for a detailed discussion.

Table4 Overviewofpolicysimulation

	Acronym	Characteristics
Reference	BC	Base Case, no new policy
Pricing	CO2tax	CO_2 tax 10,000 Y/t CO_2
	MATtax	Primary Materials tax 50,000 Y/t
	RECsub	Recycling subsidy 50,000 Y/t
	CO2taxMATtax	Combined CO_2 tax and materials tax
	MATtaxRECsub	Combined materials tax and recycling subsidy
Regulatory approaches	REGULATION	Recycling 25-90% , Industry cap 80-40 Mt CO_2
	TAXREG	CO_2 tax waste. Industry cap 80 Mt CO_2
	REGREG	Waste cap 15 Mt CO_2, Industry cap 70 Mt CO_2
	REGREG2	Waste cap 10 Mt CO_2, Industry cap 45 Mt CO_2

Results

The trends in the base case (BC, without CO_2 tax) are shown in fig. 2 The continuing growth of environmental impacts and resource consumption contradicts a sustainable development. As a consequence it is necessary to formulate additional policies to reverse this trend, in case sustainable development is taken seriously.

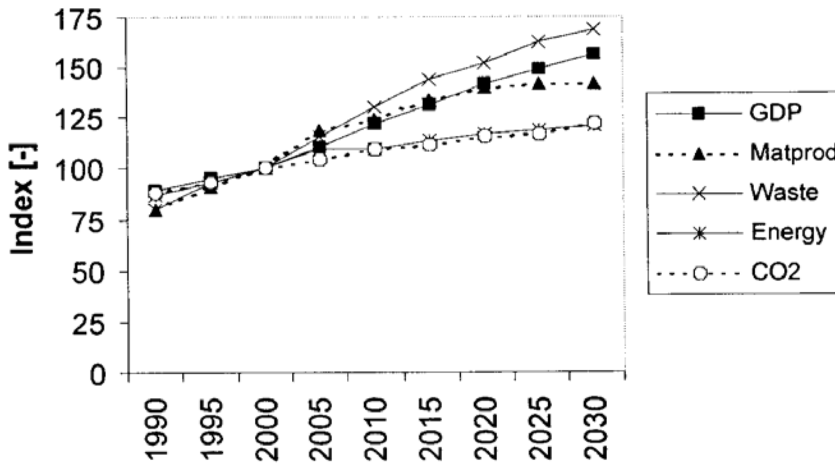


Fig.2 BC trends.2000=100.

Table 5 provides an overview of the environmental impact of pricing policies. In all policy scenarios, a 34-50% reduction of CO_2 emissions, waste and energy use is achieved. The recycling subsidy (RECsub) has a negative impact on the environment. This can be explained by the fact that the subsidy lowers the cost of materials services because of lower materials prices and increasing waste benefits, thus increasing materials demand. This so-called 'rebound effect' exceeds the positive impacts of increased recycling. This effect is less prominent in the case of a combined materials tax and recycling subsidy (MATtaxRECsub), but the high costs and low environmental benefits compared to the other scenarios suggest that this is no attractive option.

Table 5 Policy costs and policy benefits, 2015. Minus indicates an emission reduction.

Policy	Cost [bin. y/yr]	CO_2 reduction [Mt/yr]	Waste reduction [Mt/yr]	Energy demand reduction [PJ/yr]
CO2tax	145.7	-44.1 (-40%)	-3.03(-18%)	-588(-32%)
MATtax	203.4	-17.7(-16%)	-4.40(-26%)	-338(-18%)
RECsub	106.3	+11.6(+11%)	+2.61(+15%)	-115(-6%)
MATtaxRECsub	211.1	-8.7(-8%)	-2.47(-15%)	-256(-14%)
CO2taxMATtax	373.9	-55.1 (-50%)	-5.77(-347%)	-825 (-45%)

Based on the data in table 5 it is not possible to select the best of the three remaining policies. Their environmental impacts differ but their costs differ, too. The environmental performance will be expressed in monetary terms for proper comparison.

The costs in table 5 include the total reduction of consumer/producer surplus. These costs can be compared to the benefits in terms of reduced environmental effects. Combining estimates for externalities (ExternE 2001) with emission factors for industrial processes in Japan (Environmental Agency of Japan 2001) yields the benefits in table 6.

Table 6 Comparison of policy costs and benefits 2015. Positive values indicate benefits.

Policy	MATtax [bln. Y/yr]	CO2tax [bln. Y/yr]	MATtaxCO2tax [bln.Y/yr]
CO_2 benefits	+35.4~ +88.5	+88.2~ +220.5	+110.2~ +275.5
Waste benefits	+44.0~ +88.0	+30.3~ +60.6	+57.7~ +115.4
LAP*3 benefits	+22.7~ +66.0	+12.8~ +37.2	-31.3~ +90.9
Costs	-203.4	- 145.7	-373.9
Total net benefit	-101.3~ +39.1	-14.4~+172.6	-174.7~ +107.9

*3 LAP Local Air Pollution (SO_2, NO_X, particulate matter emissions)

The resulting benefits in table 6 show a wide range from a net loss to a significant net welfare gain. All three types of benefits are of similar importance. This indicates the importance of co-benefits in the policy assessment. Based on the results in table 4 it is not possible to identify the 'best' policy.

Figs. 3 and 4 show the performance of regulatory policy instruments in comparison to an approach based on pricing instruments. Total costs are compared to the CO_2 reduction effect

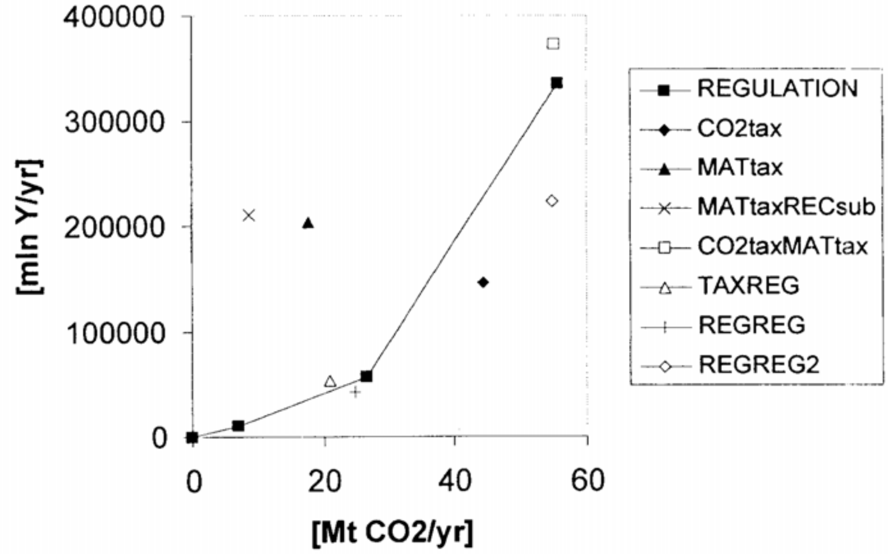


Fig. 3　Efficiency and effectiveness of CO_2 emission reduction policies, 2015.

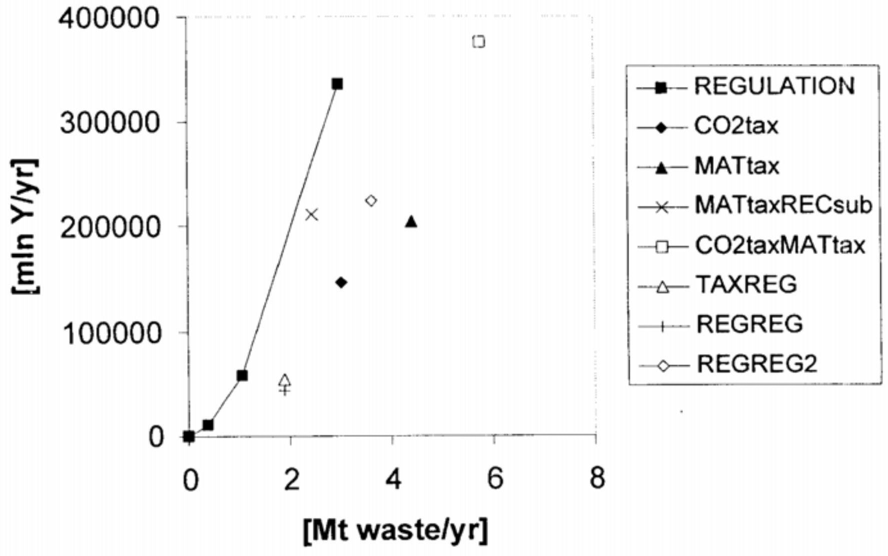


Fig. 4　Efficiency and effectiveness of waste reduction policies, 2015.

and the waste volume reduction effect. The effectiveness of policies can be measured as the x-axis value, while the efficiency can be measured as the ratio of the y and x value (the angle of a straight line through the origin). The results for a number of regulation cases suggest a fairly high efficiency, but a rather low effectiveness. REGREG and REGREG2 are quite efficient from both a CO_2 point of view and a waste volume point of view. At higher effectiveness levels, the efficiency of pricing is higher than the efficiency of regulation (CO_2 tax from a CO_2 point of view, CO_2 tax and MATtax from a waste point of view).

Fig. 5 provides a breakdown of the CO_2 emission reduction in the CO_2 tax scenario. The reference is in this case a situation with fixed energy efficiency and fixed product mix, growing proportionally with GDP. Initially in BC petrochemical demand grows faster than GDP, resulting in a negative CO_2 emission reduction. However this trend is reversed after 2015 because of market saturation. The 20-30 Mt emission reduction in BC in 2020-2030 can be attributed to autonomous improvements. Up to 80 Mt additional emission reduction can be achieved until 2025, in case a CO_2 tax is introduced. The figure shows a gradual increase of the effect of the tax, which can be attributed to a combination of increasing tax levels, technological progress and changing fossil fuel prices.

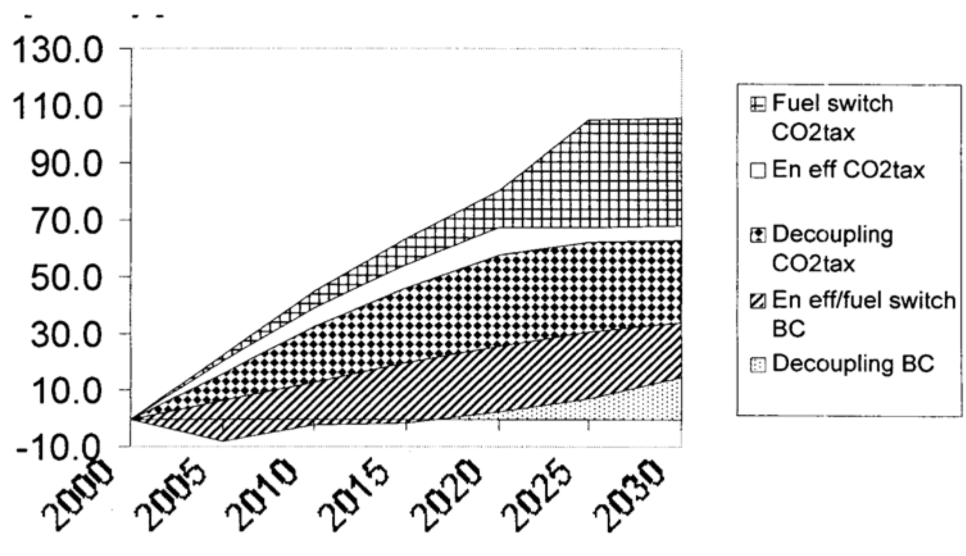


Fig. 5 Breakdown of CO_2 emission reduction, CO_2 tax policy scenario. Fuel switch includes biomass feedstocks. Energy efficiency includes increased recycling. Decoupling refers to the growth difference between GDP and petrochemical demand.

However a CO_2 tax would deteriorate the competitive position of the Japanese materials producing industry significantly. A materials consumption tax does not result in such a deterioration. Another solution may be the combination of industrial CO_2 taxes and import tariffs.

Conclusions

Packaging contributes significantly to social welfare. However the continuing growth of environmental impacts and resource consumption in the packaging life cycle contradicts a sustainable development. As a consequence it is necessary to formulate additional policies to reverse this trend, in case sustainable development is taken seriously. Plastic materials pose the main challenge in this respect. From a technical point of view it is possible to enhance the sustainability of plastic packaging materials. Major improvements in sustainability can be achieved through a combination of biomass feedstocks, increased efficiency of materials use and changes in waste management.

Integration of several policy areas such as GHG emission reduction and waste reduction may be an effective and efficient way to reach both GHG emission reduction and waste minimization. Based on this analysis it is uncertain as of yet if the social benefits of new environmental policies exceed the costs.

The results suggest the highest benefits for generic broadly applied policy approaches, since more detailed, sector-based policies are likely to disregard the interaction of many technical options throughout the packaging materials life cycle. Such generic approaches should interfere as little as possible with the competition amongst sets of complementary technical options. In particular, governments should be prudent in setting waste management targets so as not to disadvantage policies that are more efficient either at the present time or in the future. Generic pricing instruments are the only viable tool to achieve such an integration.

References

Cembureau 1999 : Environmental benefits of using Alternative Fuels in Cement Production - A Life-Cycle approach. Via Internet : http://www.cembureau.be/

Environmental Agency of Japan 2001 : Environmental load according to economic activity. Internal database. National Institute of Environmental Studies, Tsukuba, Japan.

ExternE 2001 : Summary of results for air pollutants. Via Internet :
http://www. Externe/jrc.es/All-EU+Summary.htm
Fujino J, Yamaji K, Yamamoto H. 1999 : Biomass-balance table for evaluating bioenergy resources. Applied Energy ; 63 : 75-89.
Gielen, D. J. and J. Pieters 1999 : Instruments and Technologies for Climate Change Policy. An Integrated Energy and Materials Systems Modelling Approach. Paris : OECD, ENV/EPOC/GEEI (99) 15. Via Internet : http://www.oecd.org/env/docs/epocgeei9915.pdf
Gielen, D. J., Feber,M. A. P. C. de, Bos, A. J. M. and Gerlagh, T. 2001 : Biomass for energy or materials? A Western European systems engineering perspective. Energy Policy 29, pp. 291-302.
Gielen, D. J. and Yagita H. 2001 : Assessment of CO_2 emission reduction strategies for the Japanese petrochemical industry. Journal of Industrial Ecology vol. 4, no. 3, pp. 53-73.
Gielen D. J. and Moriguchi Y. 2001 : The interaction of environmental policies. A case study for Japan. National Institute for Environmental Studies, Tsukuba, Japan. Via Internet :
http://www. resourcemodels. org/
Hekkert, M. P. 2000 : Improving Material Management to Reduce Greenhouse Gas Emissions. PhD thesis Utrecht University, The Netherlands. ISBN 90-393-2450-6.
Japan Packaging Institute 2001 : Statistics on the sale of Japanese Packaging Industry in 1999. Via Internet : http://www.jpi.or.jp/english/statictiesl999.htm
National Research Council, 2000 : Biobased Industrial Products : Research and Commercialization Priorities. Via Internet :
http://www. nap. edu/books/0309053927/html/index. html
Plastic Waste Management Institute 1999 : Development of technology for the full-scale enforcement of containers and packaging recycling law to turn into new products. Newsletter no. 17. Via Internet : http://www.pwmi.or.jp/
Plastic Waste Management Institute 2000 : Plastic products, plastic waste and resource recovery. Via Internet : http://www.pwmi.or.jp/
SAEFL 1998 : Life cycle inventories for packagings. Volume 1+2. Environmental series no. 250. Swiss Agency for the Environment, Forests and Landscape Berne, Switzerland.
Sakamura, H., Yasui, I., Morishita, K., Tanaka, K. 2000 : Life cycle flow analysis of aluminium can in Japan. Proceedings 4th international conference on Ecobalance. The Society of Non-traditional Technology, Tokyo.

IPS '01 総説

Radio Frequency Identification : Smart Or Intelligent Packaging?

Robb CLARKE

1. Introduction :

This paper will examine the differences between "smart" packaging and "intelligent" packaging. Unfortunately, these are not terms that are formally defined. This means that they are open to individual interpretation and this results in reporting that is arbitrary on a company-by-company basis or industry-by-industry basis. However, the author attempts to define what is meant by these terms, and why they are used.

Further, this paper looks at the automatic identification industry and reviews some of the major segments as they relate to smart or intelligent packaging. The focus of the paper will look at radio frequency identification (RFID) systems and explain some of the uses found in the United States.

2. Background :

Automatic Identification is a generic term describing various methods of data collection and entry. It is a world wide term that offers a wide range of capabilities. You often see the designation AIDC, which stands for Automatic Identification and Data Capture. This is descriptive of its function because all AIDC technologies have the same core capability: to read and interpret information, which is entered non-manually and stored in some form, thereby eliminating human errors associated with the data collection. Thus, they automatically identify and capture the data necessary to perform their intended task. Other terms often referring to the same generic class of technologies include: Auto ID, Keyless Data Entry, or ADC, which stands for Automatic Data Capture.

School of Packaging Michigan State University

Auto ID technologies eliminate the need for manual entry of data. Because of this, there is an immediate benefit derived from the elimination of errors that result from manual entry. Associated with the increase in entry accuracy are overall system cost reductions and timesavings. There are additional benefits that can be derived as well including, where appropriate, increased product or service quality, increased productivity, and a reduction in inventory.

All automatic identification and data capture technologies have two goals. One is to eliminate errors associated with an identification and/or data collection. The other is to accelerate the throughput process, allowing goods and/or services to be moved and offered faster than was previously possible.

There are many types of automatic identification (Auto ID). Some are common technologies such as barcodes, and others are newer applications of technology such as RFID and biometrics. Additional areas of Auto ID include smart cards, voice recognition, optical character recognition and magnetic stripes. These technologies sometimes stand alone, or they can work in conjunction with other technologies. For example, a barcode or a magnetic stripe may work completely by itself (with the appropriate reader and computer). At other times, a barcode may work in conjunction with either radio frequency or smart cards and, hence, becomes part of a "Acombination technology". Combination technologies often surpass the performance of an individual Auto ID technology.

Many technologies that use hand held scanners operate by using real-time, non-contact, two-way communications between automatic data capture (ADC) devices and a host computer where the files are stored. The communication is achieved, without hard wiring, by using radio frequency waves as the data transmission source. This use of RF is called radio frequency data communication, or RFDC. RFDC is different from RFID in that the information storage media for the ADC is not an RF tag technology. Instead, the reader for that specific technology simply uses RF to transmit the data and collect any response. Examples could be a hand held laser reader for barcodes or voice recognition systems in wireless warehouse applications.

RFDC offers two main communications possibilities, narrow band (extended range) and spread spectrum (increased speed). The decision on narrow band vs. spread spectrum is one of the keys in whether a RFDC system will work. Narrow band options (450 Megahertz range) offer greater range but have slower data transmissions rates. They also require Federal Communications Commission (FCC) licenses and are only available in the USA and Canada.

All Auto ID technologies utilize similar system components. The components are the information storage technique (or medium that is to be entered or edited), the reader that deciphers the coded information, and a computer/software component that interprets the coded information. It is also necessary to have a power source available to facilitate the transaction. Sometimes the power source is located externally and sometimes it is internal.

Some Auto ID technologies are well known and others are still developing. The use of barcodes, for example, is fairly well understood and, therefore, will not be examined in detail in this paper. However, it is worthwhile pointing out that barcodes do work well as an Auto ID technology and the biggest growth for barcodes will likely be in two dimensional (2-D) codes and the new Uniform Code Council Reduced Space Symbology (RSS) stacked codes. Readers should also be aware that some one-dimensional codes are expected to increase the number of characters in an attempt to offer true worldwide usage.

The next section of this paper will review Auto ID technologies other than barcodes. These will include card technologies and voice recognition.

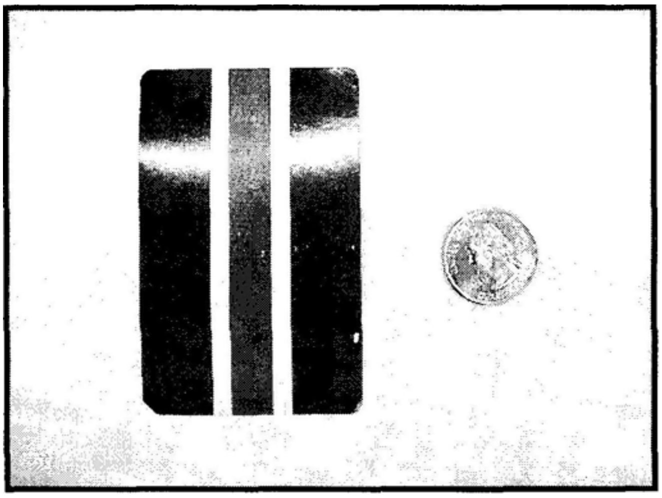
2.1 Card Technologies :

There are three main types of Card Technologies: 1) magnetic stripe, 2) smart cards, and 3) optical memory cards.

These technologies can generally be described as having a storage medium affixed to a rigid material. For example, credit cards are a technology that incorporates a magnetic storage stripe adhered to the back of a rigid plastic card. The information needed for the business transaction is embedded in the stripe on the back of the card while the rigidity of the plastic keeps the card from being bent, which would render the stripe information worthless. While most uses of this type of technology incorporate plastic cards that we would recognize, there is nothing definitive as to the size of the stripe or the card material. An example of this is the use of magnetic stripes on airline tickets or parking lot time stamp receipts.

2.1.1 Magnetic Stripe Technology :

Magnetic stripe technology uses a magnetic medium to store encoded data. The data is stored in a binary format, meaning that the information given at a particular location is either a "zero" or a "one". This is accomplished by altering the polarity of tiny " magnets " embedded in a resin coating. To extract information from a mag stripe, a reader first detects and then decodes the

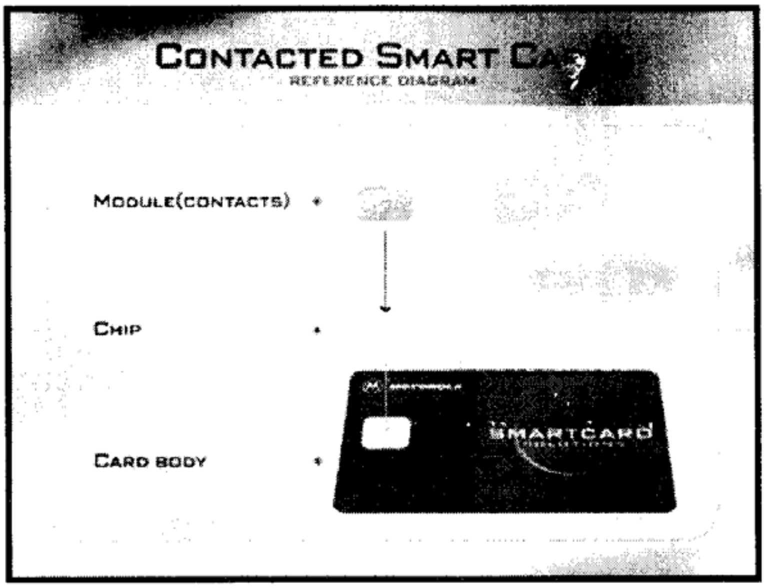


flux reversals (polarity changes). Typically, this information is translated into a human readable (alphanumeric) display.

Mag stripes can also be altered and rewritten. Alteration can be intentional or unintentional. Intentional alteration generally means it can be rewritten, but unintentional generally means that it has been erased or destroyed. Because the medium is magnetic, it can be altered or erased by proximity to a stronger magnetic field than that which originally created it. On a localized level, relatively weak magnets, such as those found in some money clips or kitchen magnets can affect the medium. Precautions should be taken to ensure that card stripes do not come into contact with other stripes in a wallet or purse. Constant rubbing of one stripe against another can cause alterations of the information contained in the stripes. This phenomenon is often noted when a credit card is used for a purchase and it will not read on the machine.

2.1.2 Smart Card Technology :

Smart cards are credit card-sized plastic cards with one or more microchips embedded in them. A smart card is much like a mag stripe card, except that the stored information is embedded in the integrated circuit (IC) chip rather than a magnetic medium. It is seen as offering much greater security than that found with mag stripe cards since they cannot be accidentally erased, but it comes at a greater cost. In essence, the credit card size smart card contains a microcomputer, complete with logic capable microprocessor and nonvolatile electrically erasable programmable read only memory (EEPROM). The microprocessor is to allow security checks which guarantee the accuracy and validity of the information stored in the IC chip.



To be technically precise, a smart card should have the logic capable microprocessor and thus, be capable of being active. However, the general class of smart cards also includes passive, memory-only cards such as debit cards. They are similar in concept to a magnetic stripe card, but with the smart card, the data is hidden and the card can hold far more data. These cards are sometimes referred to as Read-Only cards since they can only have their memory read and units deducted from the cards' memory. Passive cards offer less memory than active cards, largely because active cards need to have additional memory to perform calculations, access the memory, and make logic decisions and responses.

2.1.3 Optical Memory Card Technology :

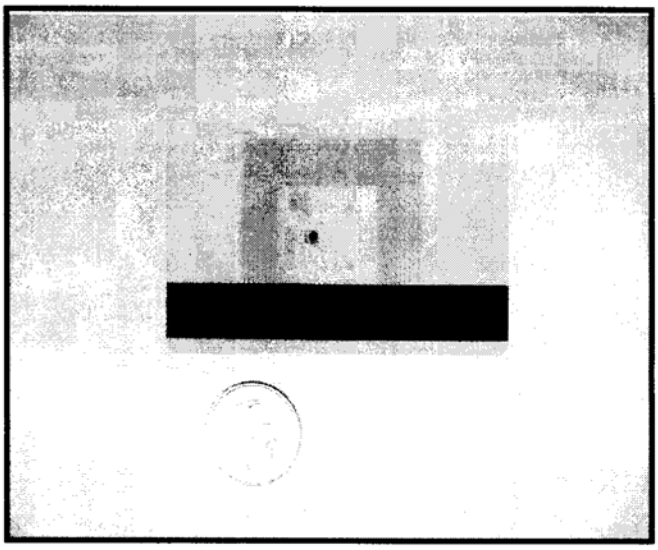
Optical Memory Cards (OMC) work like mag stripe cards but utilize a laser-recording medium instead of a magnetic medium. The principle is based on optical technology, much like a compact disc or CD-ROM. It employs a laser to write data to a reflective medium composed of silver particles suspended in a matrix. This area is typically laminated to a substrate so that it can be manufactured into credit card size units. In principle, the laser burns minuscule holes into the silver particles that can be read by a laser. The presence or absence of a hole is defined as a "zero" or "one" bit of binary code.

The medium was originally developed as a WORM technology. WORM stands for Write Once, Read Many, meaning that once the data is written, it can only be read, not modified. The technology for OMC allows for maximum storage when compared to all other card technologies.

Optical Disc technology, on the other hand, allows information to be written once, or many times if it is erasable. A CD-sized disc can currently store upwards of 750 Mb using WORM or 650 Mb on erasable optical discs. The erasable optical disc uses a polarized laser as the recording device. When heated, a magnetic field can alter the polarity of sectors on the disc. This means that no physical changes actually occur on the disc (as it does with WORM) thereby allowing it to be rewritten if desired.

2.1.4 Technology Combination Cards :

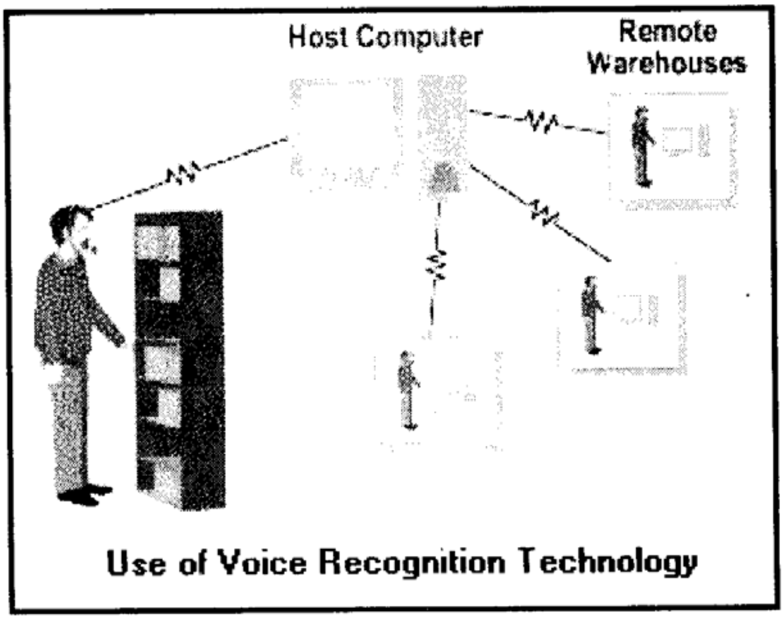
Certain cards can combine technologies to better serve a purpose. An example of such a combination card would be smart cards that also contain a magnetic stripe. This allows the card to be " dual purpose ", allowing use of the card with an existing reader system while preparing for an overall upgrade in technology.



2.2 Voice Recognition :

Voice recognition (VR) is a data input technology that allows a user to communicate with a computer using natural conversation rather than a keyboard. A headset/mike unit becomes the replacement for a keyboard and mouse, allowing hands free operations either in the plant, at a desk or in the car. The user speaks and has his/her words translated by voice recognition software into commands or text.

Voice recognition systems have been developed for specialty professions as well as for general use. Examples of specialty professions are the medical, legal and insurance industries. There is



also a high usage of VR for inspection reporting and quality assurance work. In a plant environment, it is quite common to combine VR with radio frequency transmission to communicate with a central computer system for picking, ordering or inventory.

3. Smart or Intelligent Packaging?

In preparing this paper, a literature survey found no universally accepted definitions for the terms "smart" and "intelligent" packaging. In fact, the terms are often used interchangeably. In Frontline Solutions, a leading journal on automatic identification, Gurin (2001) uses both terms in describing a single development in RFID technologies.

In the food packaging area, there is a more clear distinction. The over-all category is considered smart packaging. Under the heading of smart packaging, there are two sub-categories; intelligent and active packaging. Brody (2001) defines intelligent packaging as "…packaging that senses and measures variations in the environment or the package and its contents and communicates (this) to an observer ", while active packaging is defined as packaging that "...is engineered to sense changes in the in-package environment and to change some property to alter that environment. "

A European Commission funded project ('Actipak') is evaluating active and intelligent packaging in terms of safety, effectiveness, economic-environmental impact, and consumer acceptance. The objective is to establish and implement active (AP) and intelligent packaging

(IP) concepts within the current regulations for food packaging in Europe thereby enhancing the competitiveness of the food industry in comparison with the USA, Australia and Japan. However, these definitions do not suit automatic data entry applications.

3.1 Submitted Definitions :

Obviously, it is difficult , if not impossible, to discuss the advantages and disadvantages of a technology if one does not define the subject. It is consequently necessary to define what this article means by smart versus intelligent packaging. These definitions are simply intended to define the way the differences are viewed by the author and not as the definitive word on the subject. However, they seem sensible enough to be useful.

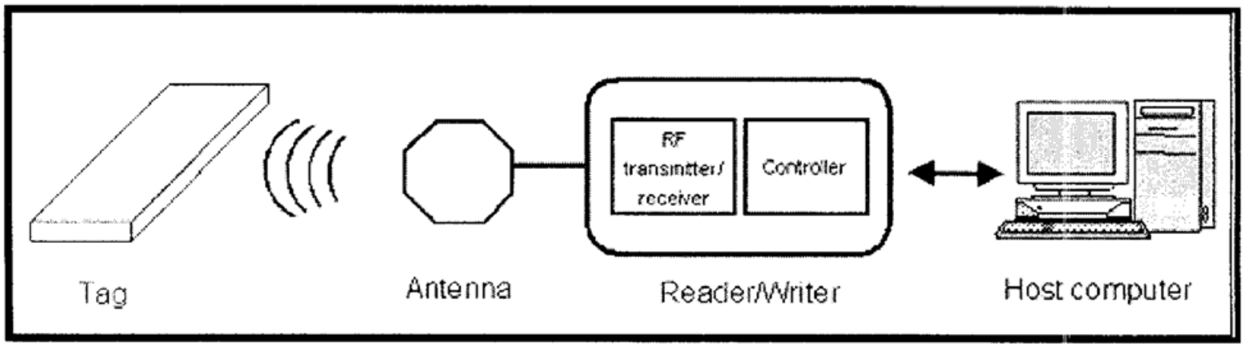
All AIDC technologies utilize various system components to complete a transaction. The components are the information storage technique or medium that is to be entered or edited, the reader that deciphers the coded information, and a computer component that interprets, and sometime stores, the coded information. Hence, the difference is assigned to the storage technique or medium. If the medium simply directs the computer to a database where the information of interest is stored, that is a different process than if the database actually travels in the storage medium.

Accordingly, I would define smart packaging to be packaging that allows communication with the database (by the reader and computer), but does not carry the data itself. The actual database is found in a computer file and the medium simply gives the computer the file address where the requisite information is stored.

Intelligent packaging, on the other hand, also allows communication with the database but it carries the actual database in the medium. To be truly intelligent, it should also be fully logic capable, although this would eliminate two-dimensional barcodes from consideration.

Based on these definitions, most technologies fall into the category of smart packaging. Other technologies may fall into both smart and intelligent categories, such as smart cards and RFID. Some technologies, however, will be purely intelligent, such as read-write optical discs, microprocessor based smart cards and RFID tags with read-write chips. The greatest growth market in the immediate future will occur in the RFID. Thus, an examination of1hat technology, and the attributes that make RFID either smart or intelligent, is appropriate.

3.2 Radio Frequency Identification :

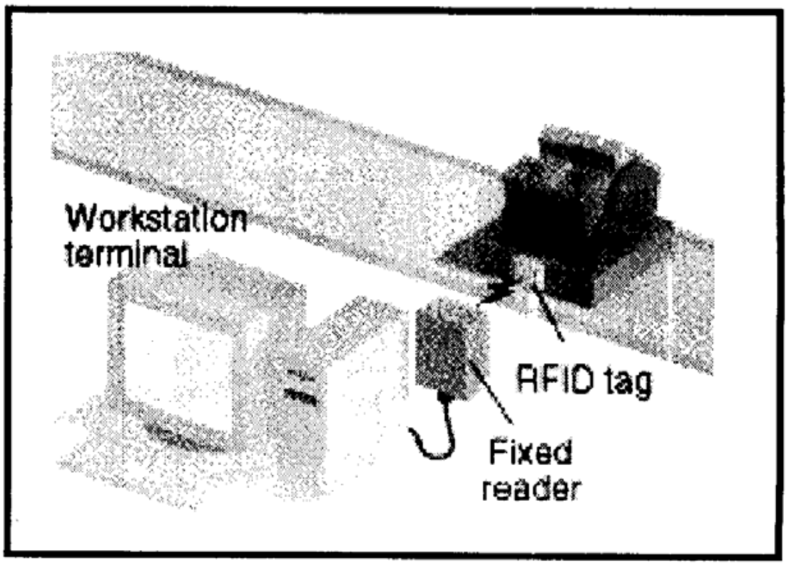


Radio frequency identification (RF1D) is a non-contact, wireless, data communication form of labeling where tags (electronic labels) are programmed with unique information and attached to objects for identification or tracking. Readers, using RF signals for communication, read these tags. A reader is actually a bundled communication device incorporating an antenna, a transceiver (transmitter/receiver) and decoder. When an RFID tag passes through an electromagnetic zone, it detects the reader activation signal. The reader decodes the data from the tag and the data is then transferred to a host computer for processing.

Tags can simply acknowledge their presence, carry price or product code, or they can hold extensive information, such as manufacturer, date of manufacture, operator and carrier information, date of delivery, put-away location, etc. The greater the amount of information stored on a tag, the higher the cost. Fortunately, RF prices are dropping as the technology develops.

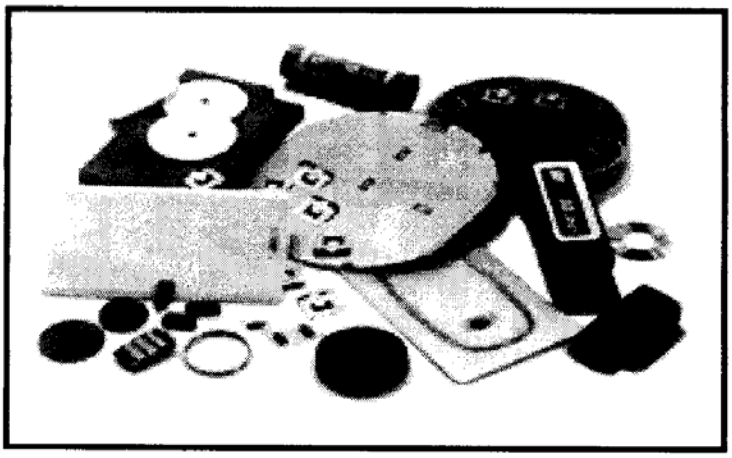
Currently, the major benefit of RFID is the ability to track moving objects, although extensive work is being done on replacing bar codes for retail applications (Ashton). One of the biggest advantages of RFID technology over bar coding is the contact-free ability to read and/or write to tags, even through all kinds of non-metallic materials and often without a line-of-site. It can often work in hostile environments, meaning that tags can operate even if they are covered in paint, snow, mud, or general grime. Difficulties in scanning due to humidity, dirt, oil or grease are minimized. Newer systems even allow RFID communication to take place with metal packages (King).

In a production environment, special instructions can be placed on a tag at the beginning of a production line and the tag can direct the various processes to work or skip that operation on a particular unit. For this system (a read/write, work-in-process system), the tag would give the instructions to a particular machine and the machine would then report its work performance to the tag. This data would then become part of the tag history. A tag can carry a separate set of instructions for every machine on a particular line. An example of this is using a tag to define the options available on an individual car order or requested performance options on an automobile engine. Moreover, at the end of the production line, the tag can download all product information into real-time inventory records and then be removed so that it can be erased and re-written with another order.



There are three main components in an RFID system. These are RF tags, also known as transponders, readers, made up of transceivers and antennas, and computers (with appropriate software). Transceiver is simply a contraction of transmitter/receiver.

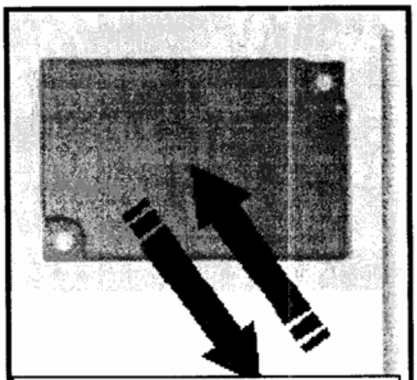
3.2.1 Tags:

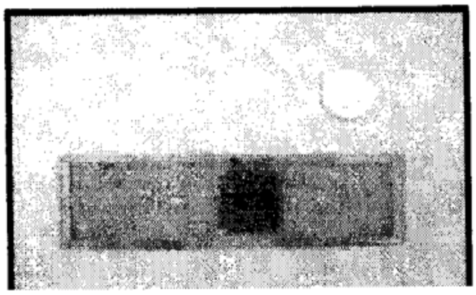


Tags come in an assortment of shapes and sizes, and can be manufactured to suit a particular application. Tag cost, size and memory capabilities fluctuate due to the specific application for which the tag will be used as well as developing technologies. This ranges from one-bit anti-theft

Electronic Article Surveillance (EAS) tags to sophisticated read/write systems with up to several kilobytes of addressable memory. Tags can be read in a stationary position or moving upwards of 70 miles per hour.

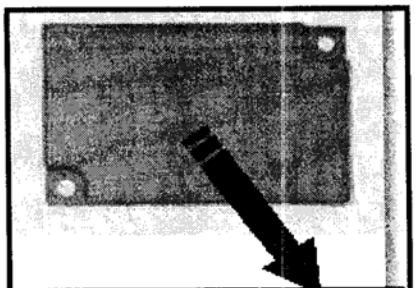
RFID tags can generally be identified as either active or passive, although there is also a semi-active hybrid. Tags are considered active if internal batteries power them. These tags are normally read/write capable. This means that, in addition to being read, the tag data can be rewritten or added to, if required, by the reader. Active tag size and memory capability varies based on the specific application for which the tag will be used.

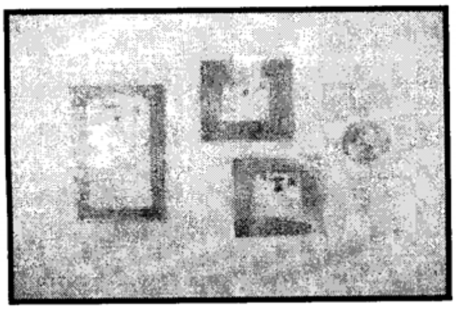

Active, Read/Write Tags



Active tags have a greater read/write range - claims of up to 4 kilometers (Harrod, Das) - because of the power of the internal battery. However, this usefulness comes at a price and that is a larger size, higher cost, and a defined lifespan. Still, it is common to have an active tag give years of service (McGlade).

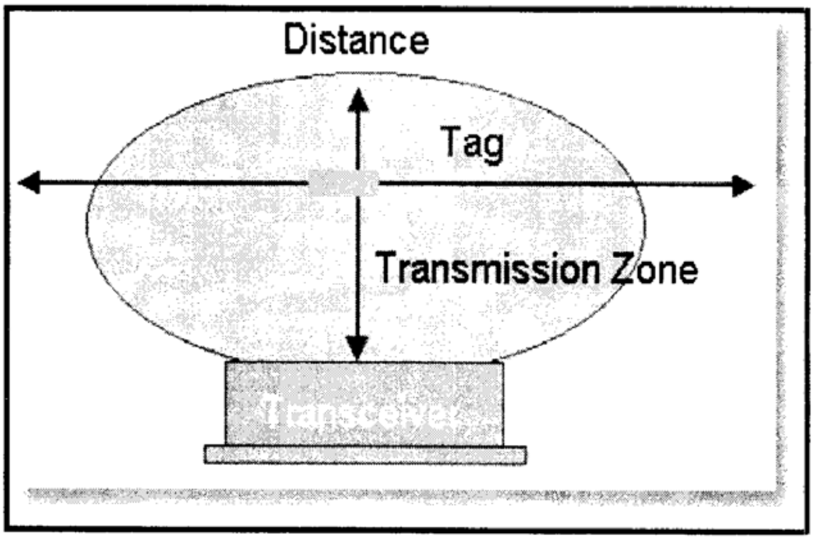
Passive tags do not have an internal power source and obtain operating power directly from the reader. As a result, they are smaller, lighter, cheaper, and demonstrate a virtually unlimited life span. They require a more powerful reader and have shorter read ranges than active tags, often centimeters. Passive tags are often " Read-Only ", meaning they are pre-programmed with a unique input and this data cannot thereafter be modified. Passive tags typically define a specific location in a database that contains the requisite information, the same way a barcode references database information.


Passive Tag (Read Only)



3.2.2 Transceivers :

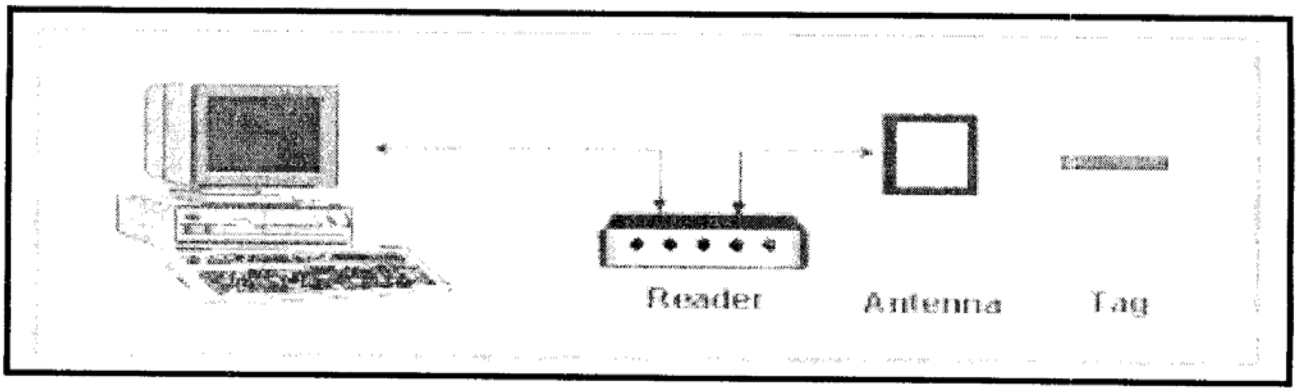
The transceiver/antennae combination, typically referred to as a reader, provides the energy for data transmission and reception between the tag and transceiver. In this way, the transceiver controls the system's data acquisition and communication, regardless of whether that be reading or writing. An electromagnetic field generated by the transceiver determines the dimensions of the transmission zone. As a tag enters this zone, data transfer takes place without any physical



The selection of a transceiver typically depends on the following characteristics: the model, shape and mounting requirements, the transmission zone dimensions, and the proximity to the next closest reader. Generally, transmission range, data transfer rate, and the dampening effects of any overlying materials increase with frequency while absorption of the signal b} metal decreases with frequency.

3.2.3 Antennae:

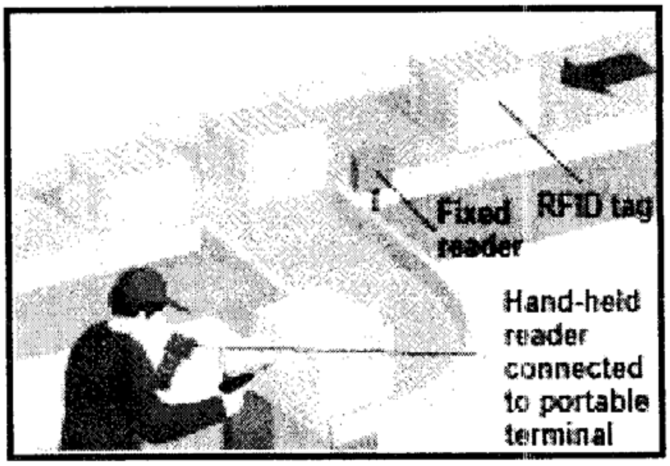
The antennae are the conduits between a tag and the transceiver. They radiate radio signals that

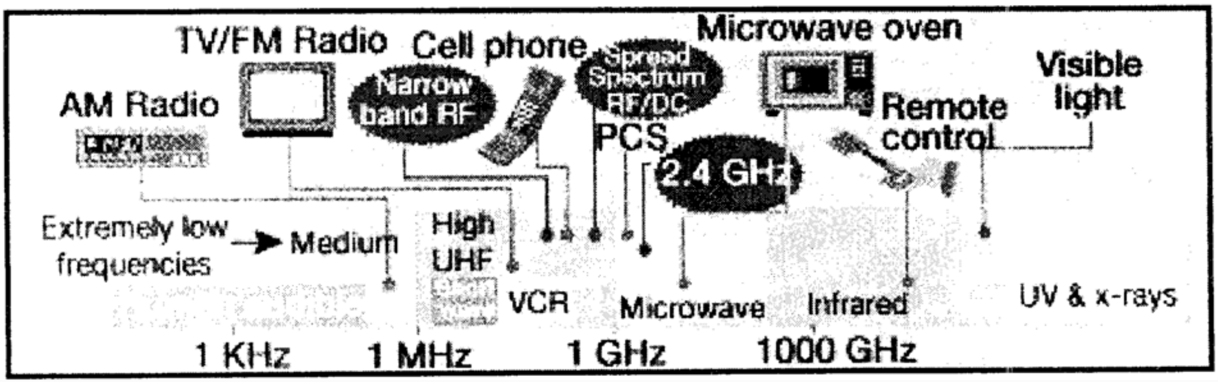


activate the tag, and then read and write the particular data to it. Often, the antenna is bundled with the transceiver and decoder and is then considered to be a reader. The reader can emit radio waves from under 1 inch to nearly 100 feet, depending upon the output power and frequency. It can therefore be utilized either as a handheld or a fixed-mount reader. Antennae can be metal or conductive ink. Ink antennae can be printed in a variety of patterns, and vast research is being done on the optimal design pattern (Moschella).

3.3 RF Frequencies:

In the United States, there are four common frequencies in use. They are: low frequency at 125 kilohertz (KHz); high frequency at 13.56megahertz (MHz); ultra high frequency(UHF)at915MHz; and microwave at 2.4 gigahertz (GHz). Certainly other frequencies are used, but these remain the predominant ones. As the utilized frequency rate is increased, both tag and reader costs typically increase.





Currently, most continents have different frequencies allotted to use by radio frequency identification methodologies. Finding the correct frequency for use is a difficult task, given the dynamic complexity of many industrial applications. This is compounded by the demands of trying to define a truly global RFID reader/tag system. A " universal " approach has been created to try to minimize the worldwide differences in frequencies. This approach, announced by the EAN International and the Uniform Code Council (UCC), developed the Global Tag (GTAG) initiative, which promotes a global supply chain standard for RFID used for applications such as container identification and tracking. The GTAG was recently modified to use the UHF frequency range of 862 - 928 MHz, although the original proposal was to use the frequency range of 862 - 870MHz. This was done because no single band in the original proposal was available for worldwide application.

This proposal does not solve all frequency issues although global standardization is a necessity for worldwide commerce. For example, there has been little progress on regulations for operating distances on a global basis. UHF systems in the US can read2to 3meters, which is key for supply chain management. However, in Japan UHF cannot be used at all, and in Europe, regulations only allow a reading distance of 0.7 meters (Doerner). Even if a tag could be read, because of the range of frequencies used on different continents, the reading of the data is not as robust as it would be if it were only read at one frequency.

4. Summary:

RFID, one of the Automatic Identification technologies, can be classified as either smart or intelligent packaging, depending on the definitions utilized by the classifying company or industry. This classification can apply to other Auto ID technologies, as well. However, there is no universally accepted definition for either smart or intelligent packaging.

RFID can accurately be described as "Intelligent Packaging" when the packaging technology has the ability to carry the requisite database within the package system, and includes a microprocessor to carry out logic functions. It would be described as " Smart Packaging "' if it does not have the capability to carry out it's own logic function, or does not carry the entire database within the package system.
"Intelligent Packaging", according to these definitions, exclude barcodes, chipless RFID tags, magnetic stripe technologies and most areas of Automatic Identification. However, these Auto ID technologies can accurately be described as "Smart Packaging" in that they carry, or carry out, actions that allow identification, measurement, tracking, integration or modification of the package in it's environment.

5. References

Anon. , *" Smart Cards Make for Smart Festivals "*, Business Solutions, January 2000, pp. 98-99.
Ashton, K. , *" The Electronic Product Code - The Next Wave of the Computer Revolution? "*

Smart Labels 2001 Conference, Cambridge England, September 2001.
Brody, A., *" What's Active About Intelligent Packaging? "*, Food Technology, Vol. 55, No. 6, June 2001, pp. 75-78.
Bylinsky, G., *" Smart Tags for Tracking Parts and Products "*, Fortune, June 26 2000.
Dalton, G., *" If These Shelves Could Talk "*, The Industry Standard Magazine, April 2, 2001.
Doerncr, E., *The RFID Breakthrough*, Global ID, June 2001, pp. 56-59.
Harrop, P.J. and Das, R. *" Smart Labels: Low Cost RFID Technologies and Trends "*, IDTechEx Ltd. Workshop, Smart Labels 2001 Conference, Cambridge England, September2001.
Gurin, R., " Packagers think outside the box: Leaders test RFID for supply chain overhaul ", Frontline Solutions, May2001.
King, P., *" Smart Label Applications in the Beverage Industry "*, The First International Smart Labeling Conference, Chicago Illinois, April 2001.
McGlade, M. , *" Achieving Efficient Global Logistics Execution "*, Smart Labels 2001 Conference. Cambridge England, September 2001.
Moschella, D., Fractal Antenna, Personal conversation, Smart Labels 2001 Conference, Cambridge England, September 2001.
Schultz, G.. *" RF Heavyweights Team Up for Smart Tag Standardization "*, ID Systems, Vol. 21, No.5, May 2001, pp. 42-46.
www.vocding.tno.nl/PS.cfm?PNR=Actipak