Smart Trash - RFID as Recycling Green Technology

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No Disclosures

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Learning Objectives

- Describe the makeup and basic functionality of RFID
- Evaluate the environmental impact of RFID on the environment and on waste streams
- Analyze potential benefits to RFID in healthcare waste disposal

Radio Frequency Identification (RFID)

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Types and Uses

Early Evolution

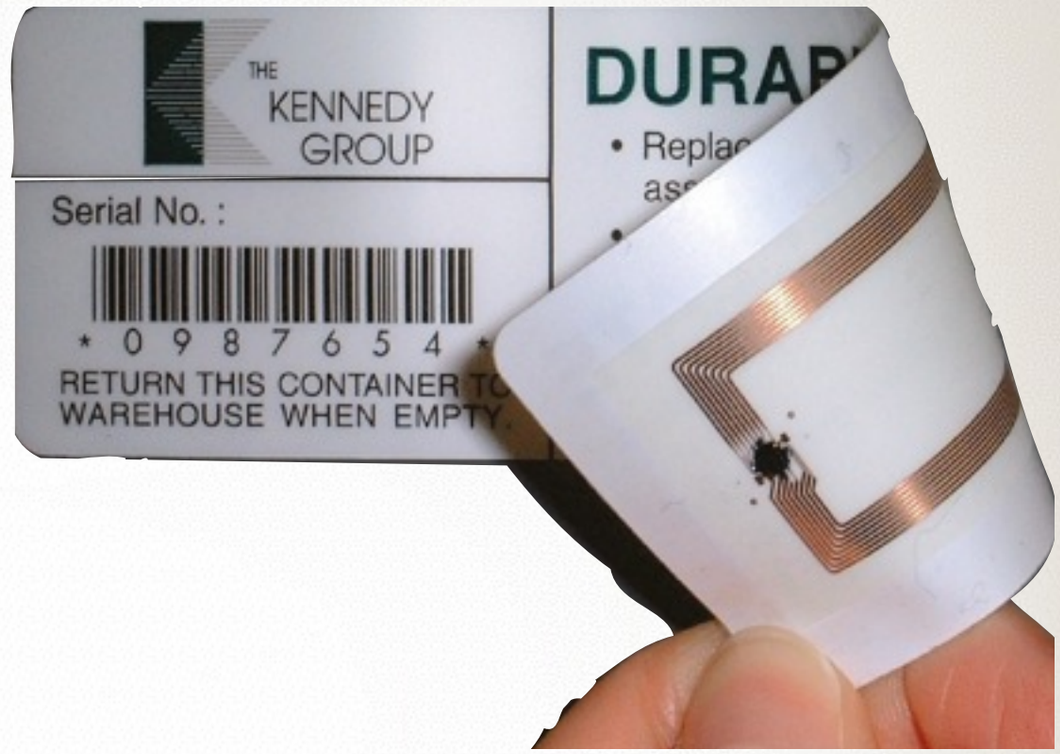
- WWII - friendly aircraft ID
- 1973 - first patent
- 1990s - commercialization
  - Toll payments
  - Large item tracking

- Transition - 1999 - MIT's Auto-ID Center

http://www.rfidjournal.com/articles/view?1338/2

Components

- Tag
  - On object
  - Computer chip
  - Antenna
- System
  - Reader (transceiver)
  - Middleware
  - Software application



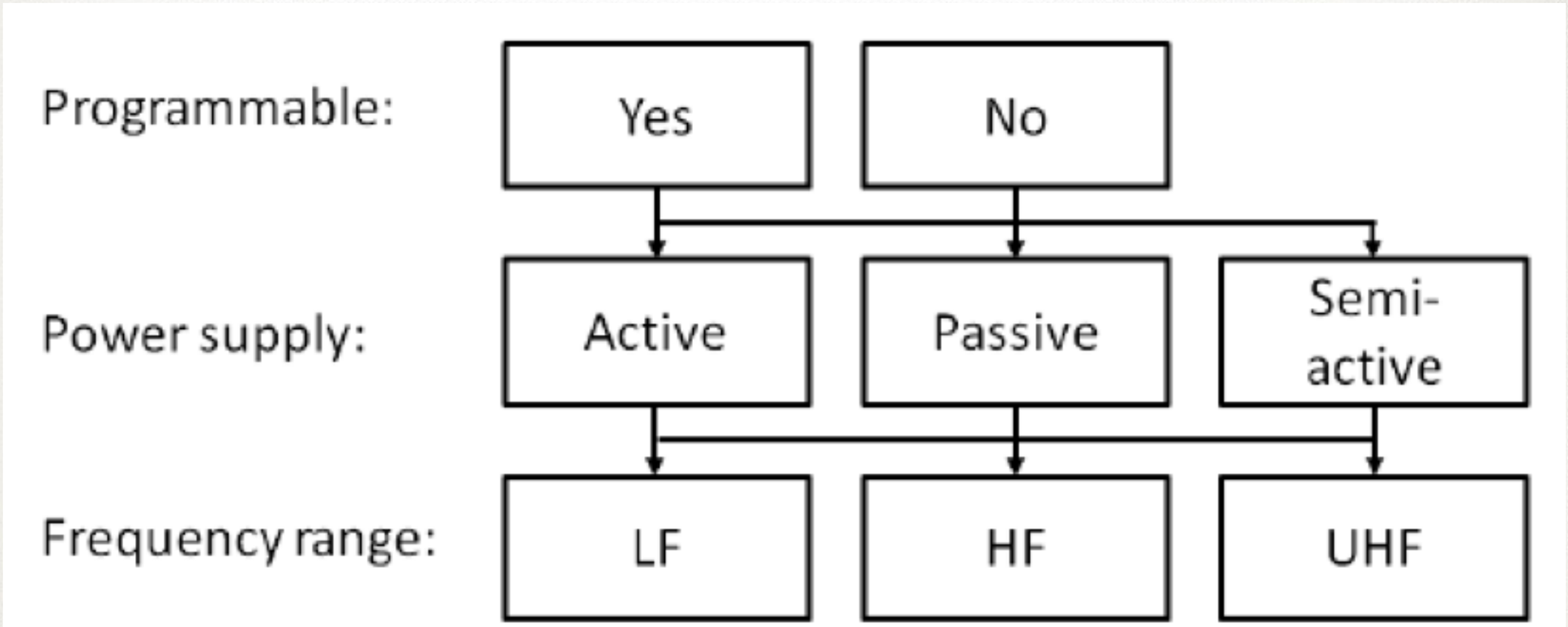
Interaction

- Reader sends radio signals
- Activates the tag
- Reads tag data
- Writes data on tag (sometimes)

Auto-ID Technology

	BarCodes	RFID
Line-of-sight	Required	None
Distance	Short	Longer
Cost	Cheap	More Costly
Data	Very little	Much, much, more

Types and Uses



Types and Uses

Frequency range:	LF	HF	UHF
	30-300 KHz	30-300 MHz	300-3000 MHz
	Access Control	Smart Cards Asset Mgmt.	Large or expensive objects

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Power Supply Determines Tag Type

- Passive - powered by reader
- Semi-active - battery assisted but no active transmitter
- Active - have power source (greater range, greater expense)

Comparison

Tag type	Passive	Active
Lifespan	Long (simple, light, small, envir. tol.)	Shorter (complex, limited by batt life)
Distance	Short	Longer
Cost	Cheap	More Costly
Data	Limited	Much, much, more
Application	Many uses, smaller items	RTLS, Sensors, large items

Content and Assembly

RFID Manufacturing

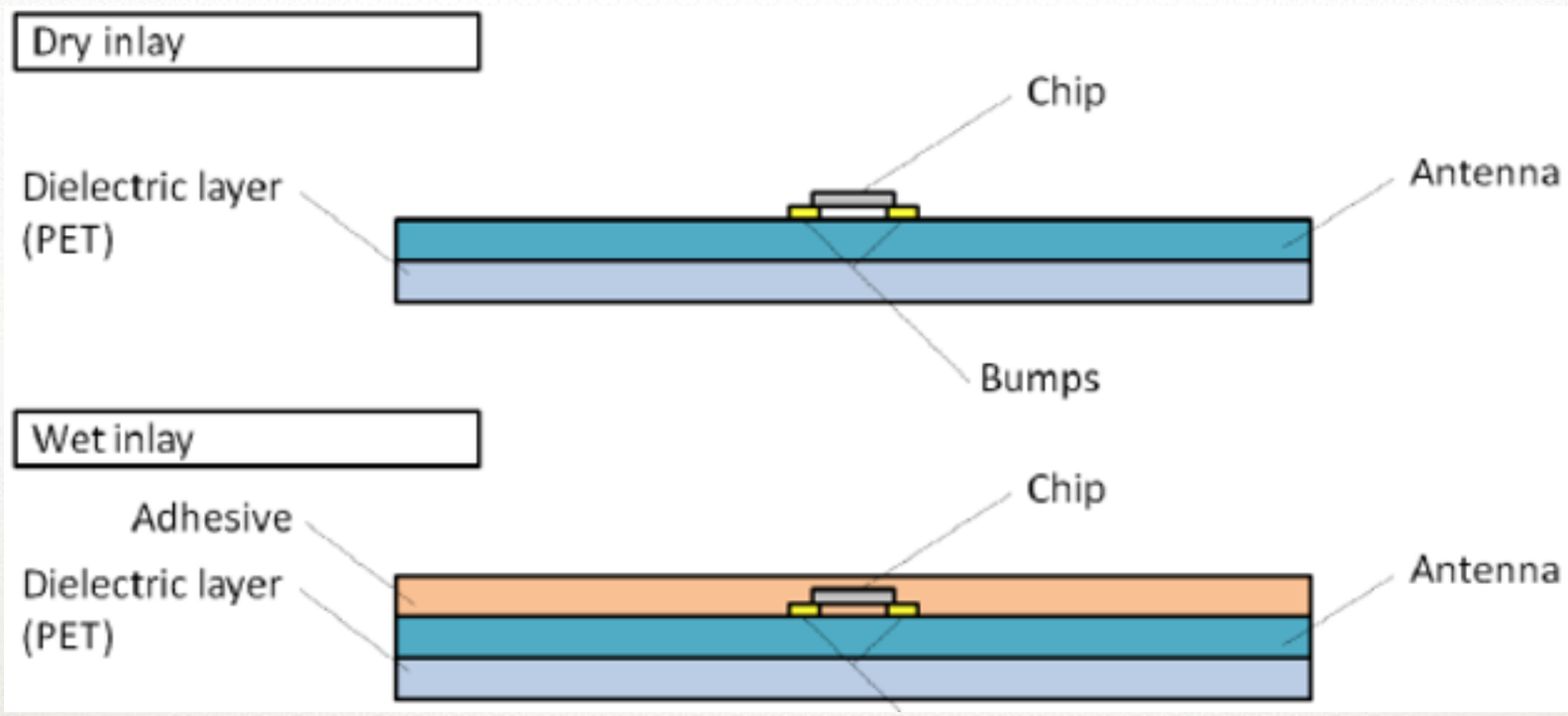
- Integrated circuit (wafer) - chips
- Antenna
- Inlay
- Label conversion including object

Antenna Manufacturing

- Subtractive - most common
  - Copper or Al-clad laminate - etching
  - Al foil - Stamping
- Additive
  - Electroplating - metals
  - Printing - conductive inks

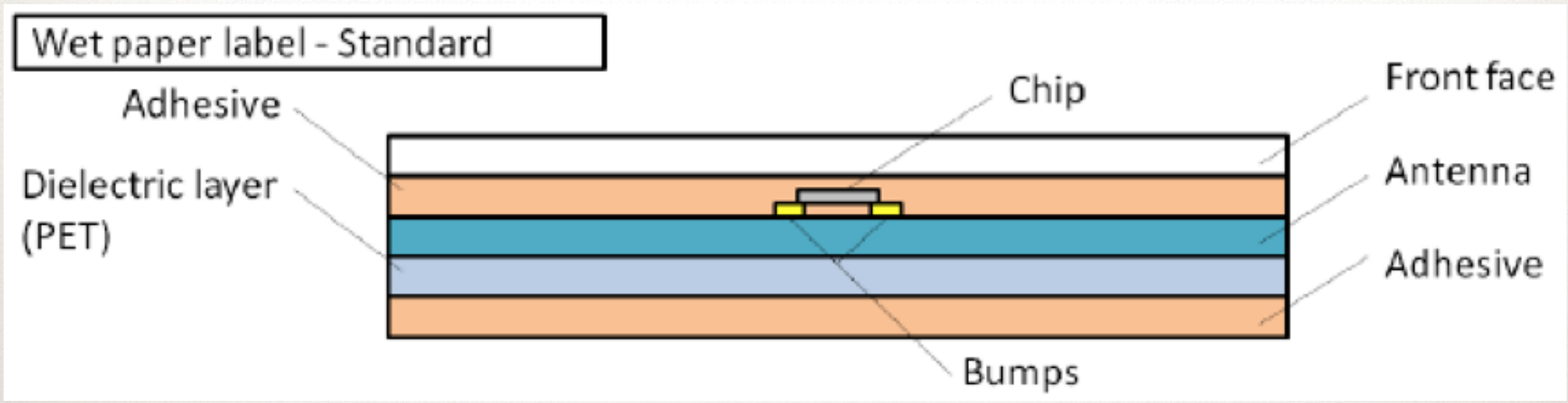
Inlay

- Inlay - created by chip and antenna bonding
  - Dry - no adhesive
  - Wet - adhesive makes inlay "stickable"



Label

- Label - wet paper label
  - One or more layers -
    - Front face - paper
    - Backing - adhesive



Material composition of RFID labels				
Label dimensions	**mm^2**	4171	2219	894
Breakdown of component	**Material**	Mass [mg]		
Face material	PP	189,3	100,7	40,6
	Paper	375,1	199,6	80,4
Adhesive	Acrylate	84,4	44,9	18,1
IC	Silicon	0,1	0,1	0,1
IC bumps	Gold	0,01	0,01	0,01
ACP (Anisotropic Conductive Paste)	Epoxy-based material	0,2	0,2	0,2
ACP metal	Nickel	0,01	0,01	0,01
Adhesive	Polyurethane	28,5	15,2	6,1
Antenna	Copper	267,4	142,3	57,3
	Aluminium	38,6	20,5	8,3
(printed)	Silver	28,0	14,9	6,0
(printed)	Bonding agent	11,8	6,3	2,5
Substrate	PET	290,7	154,7	62,3
Adhesive	Acrylate	112,9	60,1	24,2
Total with copper antenna	without face material	**784,2**	**417,5**	**168,3**
Total with aluminium antenna		**555,4**	**295,7**	**119,3**
Total with printed silver antenna		**556,7**	**296,4**	**119,5**

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Environmental

Contaminant

Footprint

- CO2 equivalents
- Organic and inorganic
  - Metals have greater footprint
- Market value assumes extraction and recycling
- Feasible value assumes extraction is impossible

Component	Material	Carbon footprint (values rounded)
Face material	PP	3.50 $kgCO_2/kg$
	Paper	1.35 $kgCO_2/kg$
Adhesive	Acrylate	3.34 $kgCO_2/kg$
IC	Silicon	85.41 $kgCO_2/kg$
IC bumps	Gold	18,722.00 $kgCO_2/kg$
ACP	Epoxy-based material	3.34 $kgCO_2/kg$
ACP metal	Nickel	5.94 $kgCO_2/kg$
Adhesive	Polyurethane	3.34 $kgCO_2/kg$
Aerial	Copper	3.97 $kgCO_2/kg$
	Aluminium	14.90 $kgCO_2/kg$
	Silver (in print)	155.48 $kgCO_2/kg$
	Bonding agent (in print)	3.34 $kgCO_2/kg$
Substrate	PET	3.18 $kgCO_2/kg$
Adhesive	Acrylate	3.34 $kgCO_2/kg$

Sources: [ecoInvent v2.2 2011]; [GEMIS v4.7 2011]; [Probst 2011]; [

Footprint

- Antenna (aerial)
  - Al - lowest CO2
  - Copper ~15% more
  - Silver ~ 110% more
- Gold ~40-85% of value depending on tag size
- Silver is lowest by weight, but greatest value and CO2
- Organic components main CO2 cost due to weight (PET) - Polyethylene Terephthalate (resin - Dacron)

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Waste Stream

- Waste stream definitions poorly defined
- Define by composition not waste source
- Industrial and special commercial waste
  - Responsibility
  - Composition
  - Hazardousness
  - Recyclability

Waste Stream Determinants

- Tag type/quantity
  - Mostly passive (’21-242B)
  - Active <1%
- Application - Closed-loop
  - Reused - asset mgmt., intralogistics, security
  - Passive encapsulated, active, or semi-active
- Application - Open-loop - passive tags
  - Remains with item, accessed by multi systems
  - Consumer packaged goods (CPGs), supply chain

Waste Stream Determinants

- Product-related application area
  - What part of the item is it attached to
    - Item itself, in packaging (paper, plastic…)
- Likely waste stream
  - Active - electronic device - separate
  - Passive - disposed with material

Stream Dependent

- Bound to single material or complex object
- Contribute to stream materials, or contribute unwanted components

Can We Recycle Tags

- Must extract tags from waste streams
  - Eddy current separator/electromagnetic sensor sorting tested
- Required for recycling allocation
- Recycled only if attached to nonferrous metal pre-concentrates

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not feasible

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- Recycled only if attached to nonferrous metal pre-concentrates

Recycling and Other Recovery

- Energy recovery
  - Thermal conversion
    - Increased emissions
- Material recycling
  - Final purity
  - Extensive purification or decreased yield

Metallurgic Recycling Routes

- Copper/silver - economic & environmental targets
- Copper refining can recover gold and silver
  - Aluminum's reductive oxides - Value?
- Aluminum refining - alloying elements dissolve
  - Silver, gold, copper, silicon, nickel lost

Healthcare Waste and RFID

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Healthcare Waste

- Can be health risk
- Mixed with safe waste (80% safe)
- Multiple sources contribute to stream
- 1-5 kg of waste/bed/day

Track What?

- Waste classification
- Waste nature and origin
- Transport date
- Responsible parties
- Ensure materials arrive for incineration
- Illegal dumping

Requirements

- Training
- Infrastructure and standards
- Tag design for different objects
- Data includes nature and location of disposal facility

Pharmaceutical Tagging

- Composition, production date, disposal
- Combat counterfeits
- Recall management
- Control medication flow - diversion

Better Waste Handling

- Waste Classification - improved
  - Reduce uncertainty
    - Reduce cost
- Downstream - automate sorting decreasing disposal team risk
- Decreased illegal disposal

Barriers

- Some feel process efficient now
- Hazardous waste too little
- Disposal support - staff knows already
- Cannot tag organic waste
- RFID may not be the right technology
  - Requires being seen by reader
  - Trash tracking - use GSM instead to find trash outside expected path

Not Ready?

- Barriers
  - Legislative
  - Environmental
  - Technical
- Organic waste - can't tag
- Need predetermined waste streams
- Security - access rights management

RAND Conclusion

- "The use case of healthcare waste is not considered to have a high potential impact in developed countries because the amount of hazardous waste in clinics is low compared to other waste streams and non-RFID systems are already in place and working. Furthermore, most material only becomes hazardous after a particular use and is thus not tagged adequately beforehand. "

Future Trends

The Tags

Overall Trends

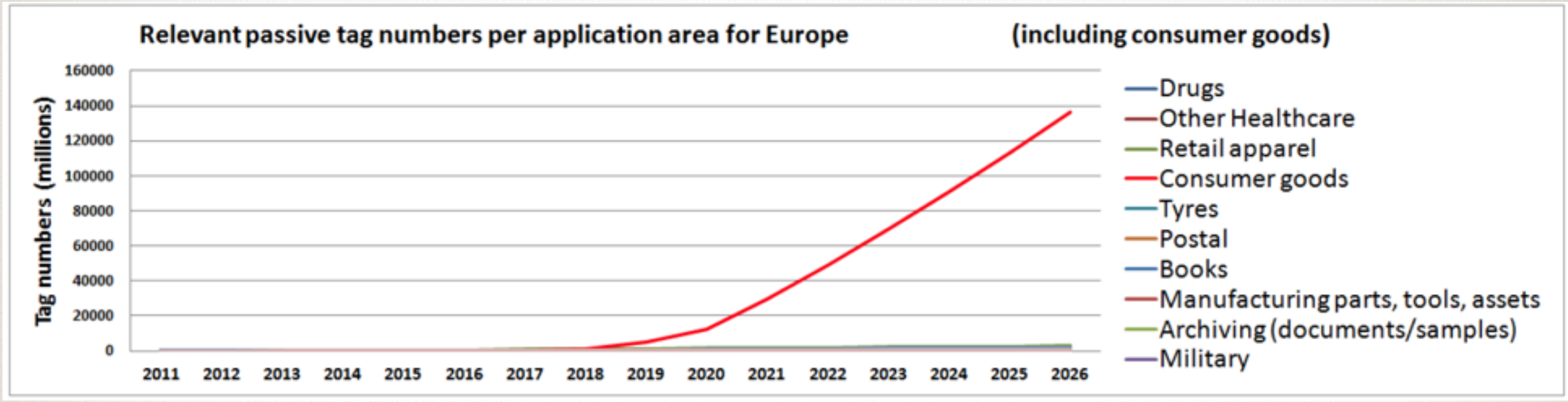
- Increased RFID tag volume over 10 years
  - Decreased active tag share
- Initial avg price increase until 2015

Table 3. Global market for active vs passive RFID tags (billions)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Active	0.06	0.07	0.08	0.10	0.13	0.19	0.29	0.40	0.53	0.73	0.77	0.79
Passive	2.25	2.81	4.34	6.21	8.18	11.6	18.4	26.0	37.2	73.5	124	243
Total	2.3	2.9	4.4	6	8	11	18	26	37	74	124	243

Source: Das & Harrop (2010)

Passive Tag Applications



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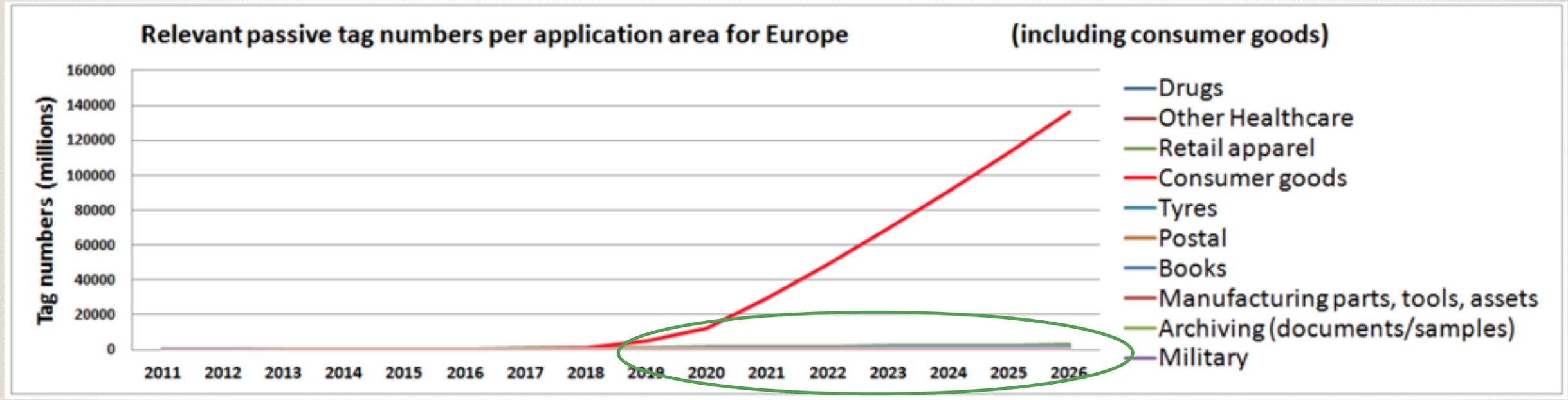

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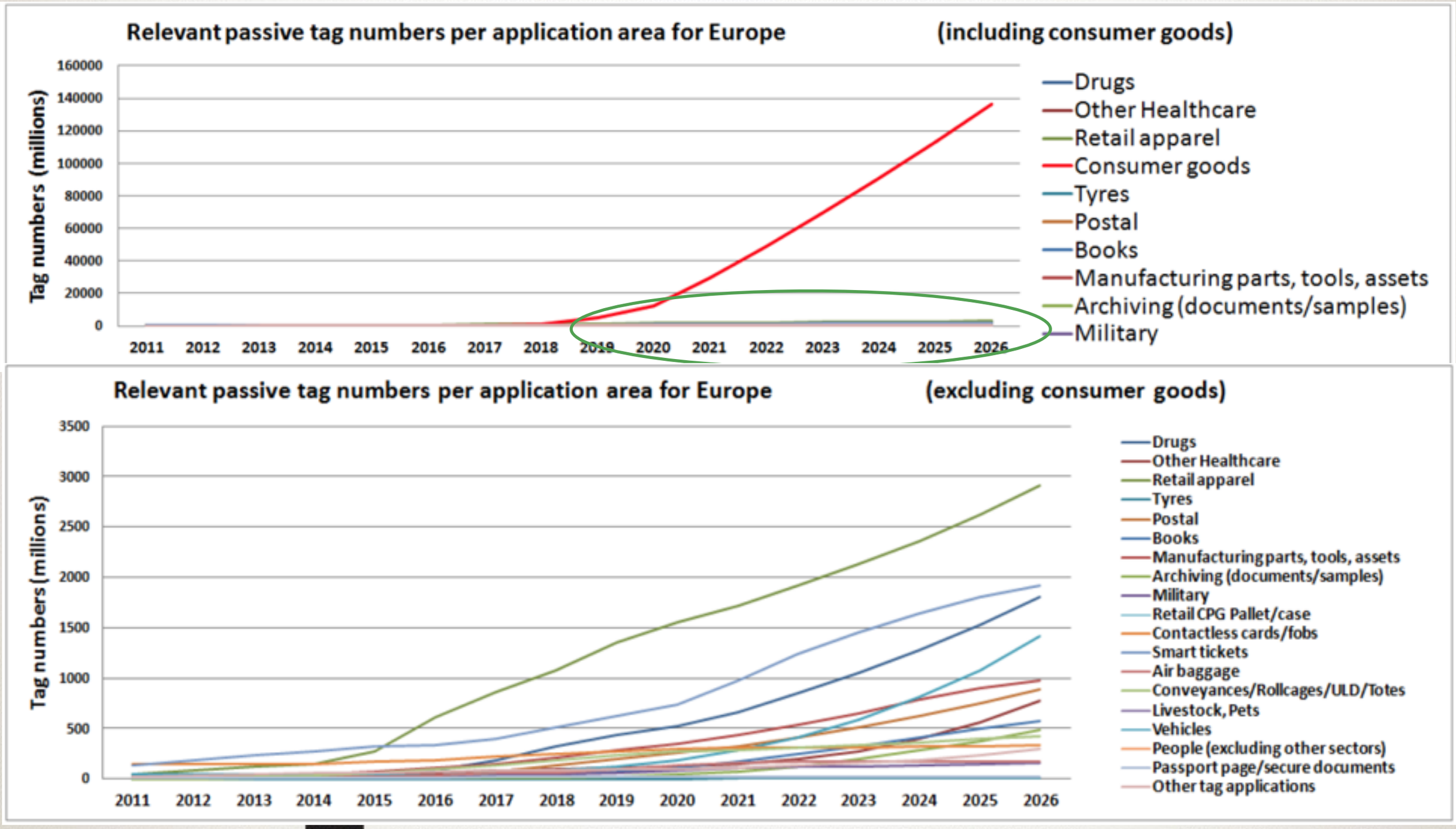

http://vimeo.com/68719955

New ID technologies

- Chipless -
  - Printed semiconductor-based tags
  - >50% production cost savings
  - Passive tags only
- Smart Active Label (SALs)
  - Implement printable battery and sensors
  - Form/cost=passive but function=active

New Material Composition

- Printed electronics
- New antenna materials (conducting inks)
  - Graphene?
- Lower environmental impact materials
- Easier to reclaim

New Processes

- Aluminum - new additive process (2010)
  - 10-100x less Aluminum
  - PET substrate obsolete

RFID For Healthcare Waste Disposal

- No process improvement or cost savings
  - Added disposal expense
  - No increased efficiency or waste capture
  - Add contaminants to waste streams
  - Increase environmental costs
- New approach feasibility
  - Technical, Legal, Commercial