Contents

- Project aim and structure
- Material identification in electronics
- Redesign of lamps
  - Design characteristics
  - Validation
  - Some other redesign examples
- Identification and sorting
- Incentive: towards a more circular economy
Develop green electronics to achieve more efficient use of resources by designing and manufacturing electronics that enable more effective recycling

Product life cycle

Raw materials → Design & Production → Final Assembly → Packaging → Sales → Waste → Use

Minimize impact

Maximize recovery

Project consortium

- Components
- PCBA
- Products
- Disposal Collection
- Separation
- Recovery

Philips Research TUD TNO All industrial partners

NXP IMEC TNO Philips Lighting BARCO PIA

IMEC Philips Lighting Optisort BARCO NXP PIA Mat-Tech Connectronics

Philips Lighting BARCO PIA

Stena

CIT Optisort NXP Stena MOS TNO

MARAS Stena CIT

Develop green electronics to achieve more efficient use of resources by designing and manufacturing electronics that enable more effective recycling
Materials and component selection

**IMEC**

<table>
<thead>
<tr>
<th>Homogeneity in</th>
<th>Material Group</th>
<th>Trace</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particles</td>
<td></td>
<td></td>
<td>mg</td>
</tr>
<tr>
<td>Lead Wire</td>
<td></td>
<td>0.57</td>
<td>mg</td>
</tr>
<tr>
<td>Lead-Free Filling</td>
<td></td>
<td>0.37</td>
<td>mg</td>
</tr>
<tr>
<td>Die Attach Material</td>
<td></td>
<td>0.08</td>
<td>mg</td>
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<tr>
<td>Est Filling</td>
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<td>0.15</td>
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<td>Silicon Die</td>
<td></td>
<td>0.07</td>
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<tr>
<td>Leadframe</td>
<td></td>
<td>0.18</td>
<td>mg</td>
</tr>
<tr>
<td>Mold Compound</td>
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<td>48.36</td>
<td>mg</td>
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</tbody>
</table>

**Full Material Declarations**

**Default Models for estimating Material Composition**
Composition of PCBA (IMEC)

- Amount of materials
- Value
- Location materials

Suitable combinations of materials for recycling (MARAS)

Geological Copper Minerals
>15 minerals e.g., Au, Ag, PGMs, Se

Designers Copper “Minerals”
>50 elements: complexly linked as alloys, compounds, materials

Geological Linkages
Various copper sulphate minerals on earth and earth

Product Design & Material Combinations create new “Minerals”

Functional Material Connections

Joined Materials Multi-material particles

materials in PCBA from lamp

Cu/Ni smelting, refining
Taking into account recycling processes

(Stena/CIT)

Recycling insight

Design guidelines for recyclability

not compromising performance or increasing cost

materials

- Use materials that can be recycled
- Use of compliant coatings
- Limit the number of different materials

connections

- Avoid fixed connections
- Break-down (by shredding/disassembly) to
  - Pieces with uniform composition
  - Pieces of relatively large size (>1 cm)

electronics

- Get PCB out in one piece (→ smelting)
- Enable easy/fast detection of materials
Redesign: MR16 with fracture lines

Standard MR16
random fracturing
PCB and shell often attached

MR16 with fracture lines
fracturing along fracture lines (in brittle materials)
most PCBs detached, inspite of screws

Assist and guide fracture in the case of brittle housing

Effect of fracture lines (TUD)

Recycling percentages (default shredding settings)

<table>
<thead>
<tr>
<th>Recycling Type</th>
<th>‘Strict’ rec.%</th>
<th>WEEE Dir. rec.%</th>
<th>QWERTY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>41%</td>
<td>82%</td>
<td>63%</td>
</tr>
<tr>
<td>(materials actually recovered)</td>
<td></td>
<td>(materials to recovery process)</td>
<td></td>
</tr>
<tr>
<td>‘Strict’ rec.%</td>
<td>67%</td>
<td>92%</td>
<td>80%</td>
</tr>
<tr>
<td>(environmentally weighted, incl. all impacts)</td>
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</tr>
</tbody>
</table>

All recycling definitions point in same direction

Weight recovered, 41%

Environmental Weight recovered, 63%, Recipe

Materials: 
- 30.6%: Ag, 0.8%: Co, 0.6%: Cu, 0.2%: Pd, 0.4%: Sn, 0.5%: Ni, 0.2%: Fe, 0.3%: Au, 0.5%: Zn, 0.5%: Other

All materials considered.
Redesign: deep-drawn MR16

Sleeve
Heat sink top
Collimators
LED PCB
Heat spreader LED PCB
Heat spreader driver
Driver
Contact pin
Driver clamp
Shell

Deep drawn MR16: recycling result

Bottom part of lamp folds into Al parts

Unless potting is used:
- Mechanical toughness needed in shredding

Increase rigidness of structure in the case of ductile housing
Effect of deep-drawing options (TUD)

Recycling percentages (default shredding settings)

Deep drawn (without potting)  Deep drawn (with potting)

‘Strict’ rec.%: 68% → 61%
(materials actually recovered)

WEEE Dir. rec.% 98% → 84%
(materials to recovery process)

QWERTY 52% → 81%
(environmentally weighted, incl. all impacts)

Weight based recycling definitions point in wrong environmental direction (due to inert material added)

Quantification and validation of design results (TUD)

Net environmental burden over 1 lifecycle (production + recycling)

-30.00  -25.00  -20.00  -15.00  -10.00  -5.00  0.00

100% collection, standard MR16, default shredding settings
100% collection, standard MR16 w/ fracture lines, default shredding settings

-30,00  -25,00  -20,00  -15,00  -10,00  -5,00  0.00
100% collection, standard MR16 w/ fracture lines, default shredding settings

Cu  Au  Al  Glass  Sn  Epoxy  Other plastics  Ag  Zn  Plastics general  Ceramics  Ni  Pd  Other inerts  Fe

Net environmental burden over 1 lifecycle

-30,00  -25,00  -20,00  -15,00  -10,00  -5,00  0.00

100% collection, standard MR16, default shredding settings
100% collection, standard MR16 w/ fracture lines, default shredding settings

-fracture lines

Net environmental burden over 1 lifecycle (production + recycling)

-30,00  -25,00  -20,00  -15,00  -10,00  -5,00  0.00

100% collection, standard MR16, default shredding settings
100% collection, standard MR16 w/ fracture lines, default shredding settings

-fracture lines

Net environmental burden over 1 lifecycle (production + recycling)
Total recovery based on process modelling (MARAS)

Losses of metals and required dilution (addition of virgin materials) known/calculated for each design. Differs significantly per case!

Redesign: Slimstyle bulb replacement (for sale in US)

Shredded before selling

1. Flat geometry eliminates need for heat sink
2. Lamphousing acts as lens
3. Sandwich construction assures separation upon crushing
4. Ultrasonic welding avoids use of connecting material
Redesign example: medical display (Barco)

Display redesign

Old design: CCFL Display

New design:
- LED
- Lighter (6 kg less)
- Less materials
- Easier to dismantle:
  - Use of indentations (small dent)
  - New EMC approach
  - Visible screws; 30 instead of 60
  - Only 1 PCBA instead of 4

Identification and sorting into well-defined waste streams (Refind)

- 2 fans instead of 4
- Alu instead of Steel
- 1 cover only instead of 2

- Use of indentations (small dent)
- New EMC approach
- Visible screws; 30 instead of 60
- Only 1 PCBA instead of 4

- Use of indentations (small dent)
- New EMC approach
- Visible screws; 30 instead of 60
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Waste treatment and material recovery  
(Stena/CIT)

Value chain and policy aspects  
(TNO)

<table>
<thead>
<tr>
<th>Business Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company level design guideline rules</td>
</tr>
<tr>
<td>Recyclability indication integrated in design software</td>
</tr>
<tr>
<td>Mandatory Full Material Declarations</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Government Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher recycling targets</td>
</tr>
<tr>
<td>Penalties for not achieving recovery targets</td>
</tr>
<tr>
<td>Standardization or specification of design aspects</td>
</tr>
<tr>
<td>Producers must recover their own materials</td>
</tr>
<tr>
<td>Building a common EU database for product recyclability</td>
</tr>
<tr>
<td>EU level design guidelines</td>
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</tbody>
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<th>Collaboration Interventions</th>
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<tr>
<td>Kick-back fee from recyclers to producers</td>
</tr>
<tr>
<td>Designers visit recycling plant</td>
</tr>
<tr>
<td>Courses for designers (assembly, disassembly)</td>
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</tbody>
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<th>Societal Interventions</th>
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<tbody>
<tr>
<td>Pushing for more reporting transparency on both collection and treatment performance</td>
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</table>
Increase incentive for producer: Circular Economy

**COLLABORATION**
- Cross value chains
- Cross business sectors
- Financial and Social Partners
- Economies of scale

**NEW BUSINESS MODELS**
- Service/Solution Delivery vs. Asset Ownership
- Easy access and affordable prices
- From transactions to relationships
- Decouple business growth & environmental impact

**REVERSE LOGISTICS**
- Enable efficient close loops
- Collection of materials
- Legislation compliance
- Incentive creation

**DESIGN for REST VALUE**
- Designs that enable multiple life-cycles with minimal loss of value, quality and energy
- Modular design for easy repair & disassembly
- Analyze product status, prognostics
- Design with mono-materials
- Create re-usable platforms

**Design for circular economy**

- Easy maintenance
- Quick disassembly
- Modular design
- Futureproof

- Optimize for recycling
- Includes and allow easy
- Future proof modular recycling
- Maintenance for optimal performance
- Design for remanufacturing at end of life

- Increase incentive for producer: Circular Economy
GreenStar: modular luminair

• Easy replacement of light engine
• Flip open cover, disconnect, slide out
• Driver unclicks also for easy replacement / upgrades
Exploring new business models

- Washington Metro with Philips Lighting

Philips was recently awarded a ten year performance lighting contract with the Washington Metropolitan Area Transit Authority (WMATA) that will upgrade the lighting in 25 WMATA parking garages. Over 13,000 lighting fixtures will be converted to an innovative, custom-designed LED lighting solution that will reduce energy usage by 68 percent or 15 million kWh per year and provide real time data on energy consumption. The new Philips system is a first of its kind and will not only make the garages brighter and safer for WMATA’s 66,000 parking garage customers, it will remove over 11,000 metric tons of CO2 from the environment. Philips will monitor and maintain the lighting solution which will be financed through energy cost savings, requiring no up-front capital costs.

“With digital lighting systems we really need to break with conventional thinking and look to the services and delivery models of the software industry to understand the future of lighting and how we can remove one of the greatest barriers to adoption – the up-front costs,” said Bruno Biasiotta, president and CEO of Philips Lighting Americas. “As a forward-thinking organization, WMATA has taken a holistic view of their parking garage solution and worked with us to finance the system through energy-savings costs, while ensuring they could deliver on their priorities. One of the benefits of this system is that real-time access to actionable data "future-proofs" the system, allowing Metro to continually adapt to their needs through real-time monitoring and measurement.”

Philips will manage the installation process then continually manage the monitoring of the system over the duration of the contract, ensuring that the system is running optimally and making any necessary adjustments that can help WMATA better serve its customers.

- Characteristics
  - Performance and/or access instead of ownership
  - Materials leasing
  - From transactions to relationships
  - Decouple business growth from environmental impact

Summarizing

- Product redesign based on recycling insight
- Cost effective, especially for new product designs
- Recycler benefits most from rest value
- Circular economy enables to increase manufacturer benefit