Green Electronics
-Sustainable Product Manufacturing-

PRODUCT DESIGN LINKED TO RECYCLING

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Leuven, 9 October 2014

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

Product life cycle

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Final Assembly → Packaging → Sales → Use → Maximize recovery → Raw materials → Waste → Minimize impact → Design & Production → Final Assembly

Minimize impact

Design & Production

Develop green electronics
to achieve
more efficient use of resources

by designing and manufacturing electronics
that enable more effective recycling

Use

Maximize recovery

Raw materials

Waste

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Project consortium

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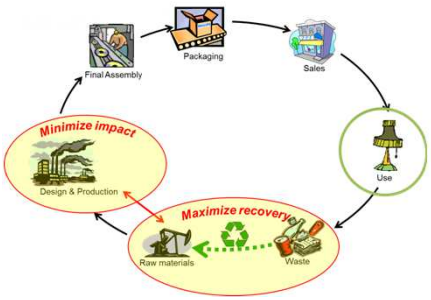
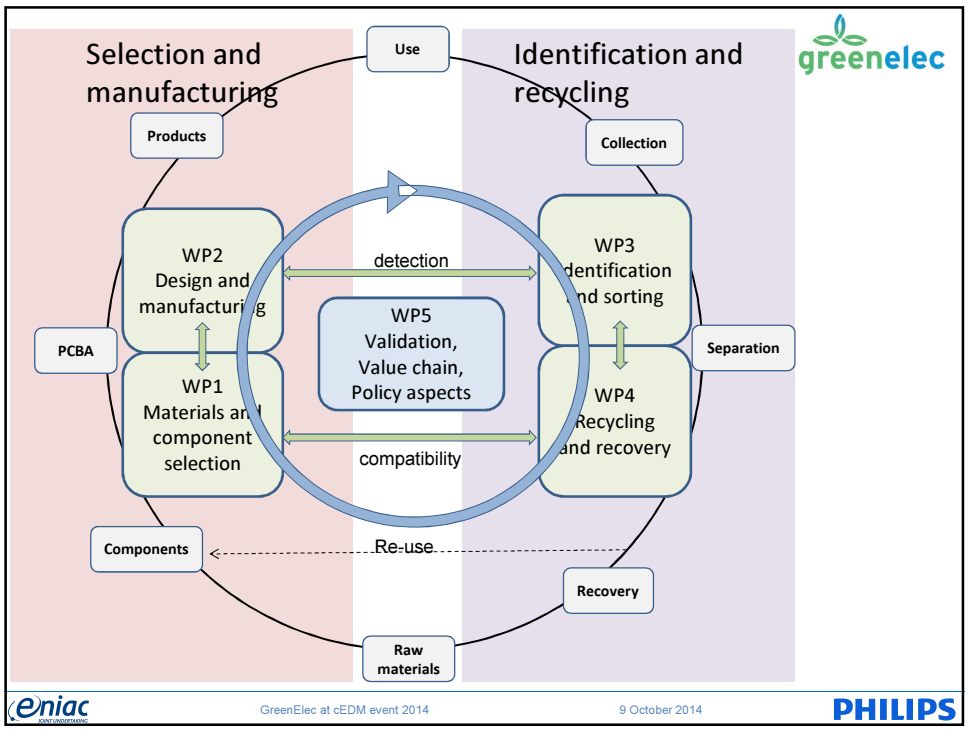
Components	NXP Philips Lighting IMEC BARCO TNO PIA
PCBA	IMEC Philips Lighting Optisort BARCO NXP PIA Mat-Tech Connectronics
Products	Philips Lighting BARCO PIA
Disposal Collection	Stena
Separation	CIT Stena Optisort MOS NXP TNO
Recovery	MARAS CIT Stena

Philips Research
TUD TNO
All industrial partners





Materials and component selection (IMEC)

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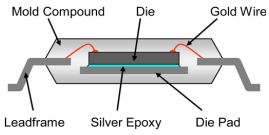
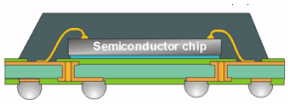
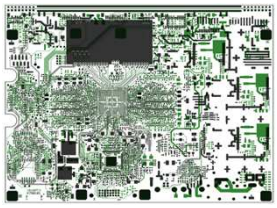
Full Material Declarations

Homogeneous M...	Material Group	Mass	UoM	+	-	Level	Substance Category	+	-	Substance	CAS	Exe...	Mass	UoM
Bond Wire		3.57	mg	+	-	Supplier	Gold and Gold Com...	+	-	Gold	7440-57-5		3.57	mg
Leadframe Plating		4.55	mg	+	-	Supplier	Silver and Silver Co...	+	-	Silver	7440-22-4		4.55	mg
Die Attach Material		5.04	mg	+	-	Supplier	Silver and Silver Co...	+	-	Silver	7440-22-4		3.9312	mg
				+	-	Supplier	Proprietary Material...	+	-	Epoxy (EP)			1.1088	mg
Ext. Plating		6.16	mg	+	-	Supplier	Tin and Tin Compo...	+	-	Tin	7440-31-5		6.16	mg
Silicon Die		37.87	mg	+	-	Supplier	Silicon and Silicon ...	+	-	Silicon	7440-21-3		37.87	mg
Leadframe		178.85	mg	+	-	Supplier	Copper and Copper...	+	-	Copper	7440-50-8		176.79...	mg
				+	-	Supplier	Chromium and Chr...	+	-	Chromium	7440-47-3		0.53655	mg
				+	-	Supplier	Tin and Tin Compo...	+	-	Tin	7440-31-5		0.4471...	mg
				+	-	Supplier	Zinc and Zirconium ...	+	-	Zinc	7440-66-6		1.0731	mg
Mold Compound		463.96	mg	+	-	Supplier	Proprietary Material...	+	-	Epoxy Resin (EP)			41.7564	mg
				+	-	Supplier	Proprietary Material...	+	-	Phenolic Resin			32.4772	mg
				+	-	Supplier	Carbon and Carbon...	+	-	Carbon black	1333-86-4		2.3198	mg
				+	-	Supplier	Silicon and Silicon ...	+	-	Silica, vitreous	60676-86-0		382.767	mg
				+	-	Supplier	Bismuth/Bismuth C...	+	-	Bismuth	7440-69-9		4.6396	mg

Default Models for estimating Material Composition







Composition of PCBA (IMEC)

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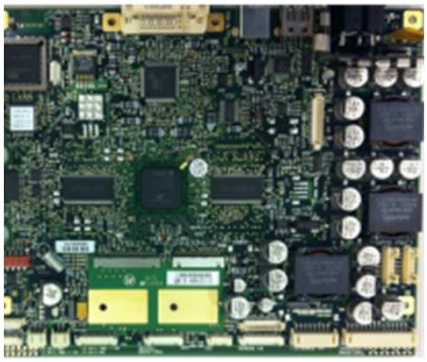

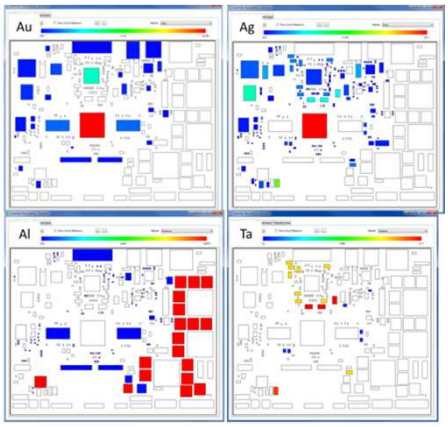

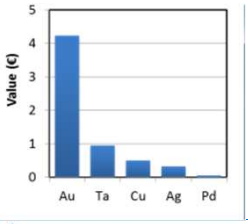

- Amount of materials
- Value
- Location materials

Suitable combinations of materials for recycling (MARAS)

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

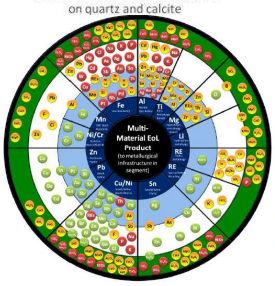
Designed Copper "Minerals"
>40 elements complexly linked as alloys, compounds, materials

Geological Linkages
Various copper sulphide minerals on quartz and calcite

Product Design & Material Combinations create new "Minerals"

Functional Material Connections

Joined Materials Multi-material particles



materials in PCBA from lamp	Ag	Au	Bi	Cu	Ni	Pb	Pd	Sn	Zn	Al(2O3)	As(O3)	Ca(O)	Cu2O	Fe (FeOx)	Mg (MgO)	Mn(O)	Sb(2O3)	Si(O2)	SiO2	Sr(O)	Ba	Dy(oxide)	Na	Ti(O2)	TiO2	W(O3)	Y(O3)	Zr/ZrO2
Cu/Ni smelting, refining																												

Taking into account recycling processes (Stena/CIT)

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Recycling insight

Design guidelines for recyclability

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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

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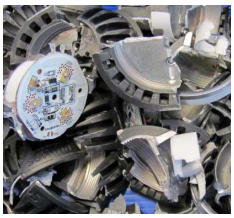
Standard MR16

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)

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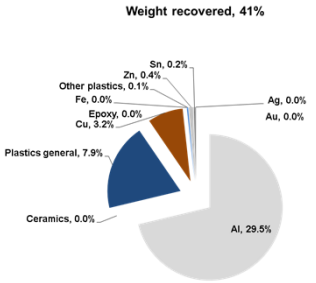
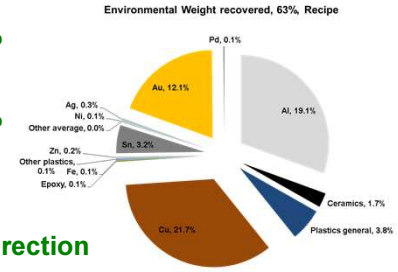
Recycling percentages
(default shredding settings)

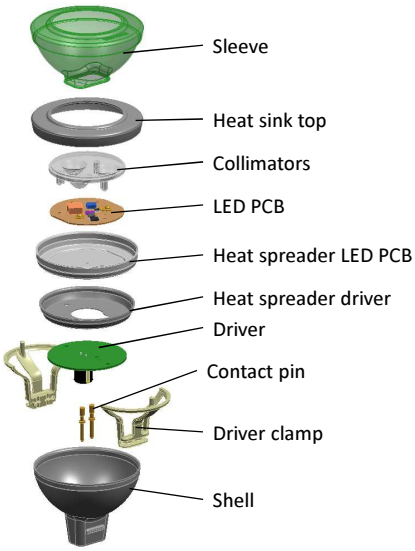
	Standard MR16		Fracture line MR16
'Strict' rec.%:	41%	→	**67%**
(materials actually recovered)			
WEEE Dir. rec.%	82%	→	**92%**
(materials to recovery process)			
QWERTY	63%	→	**80%**
(environmentally weighted, incl. all impacts)			

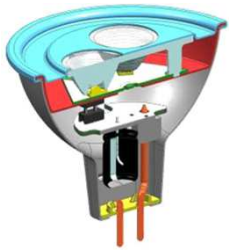




All recycling definitions point in same direction

Redesign: deep-drawn MR16



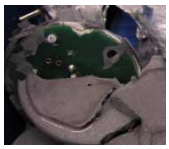


Deep drawn MR16: recycling result

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)

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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)

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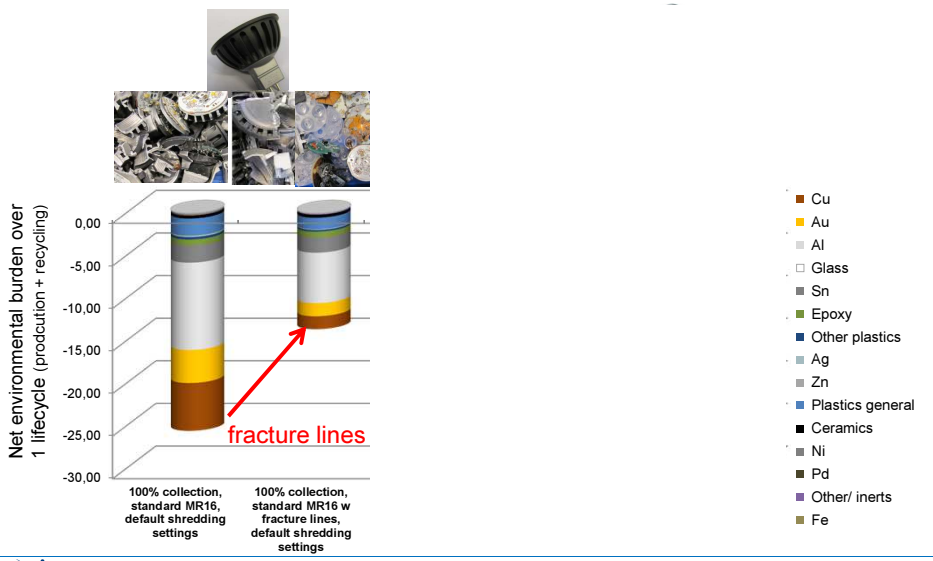
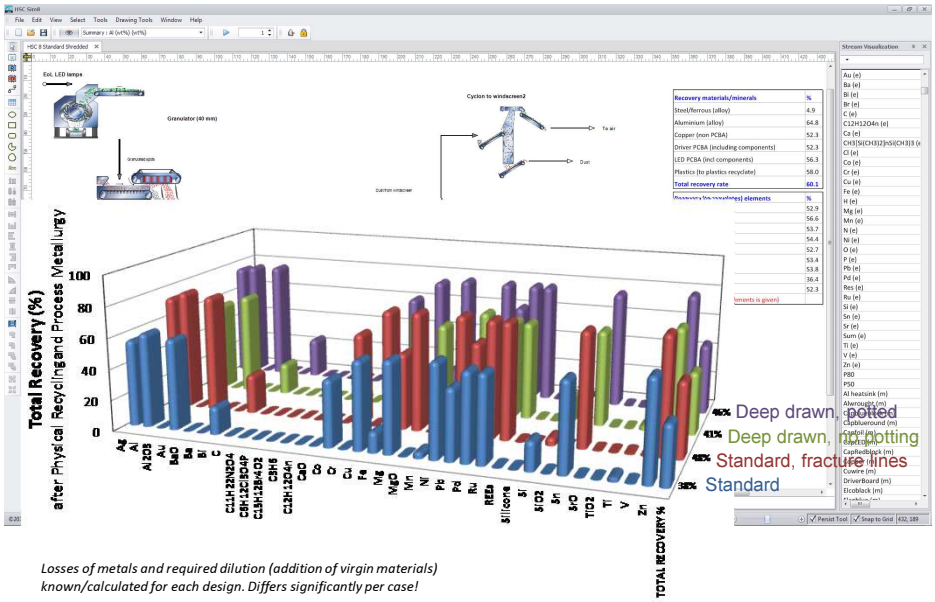


Total recovery based on process modelling (MARAS)

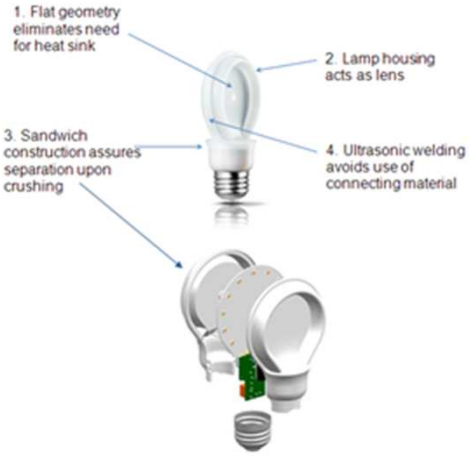


Losses of metals and required dilution (addition of virgin materials) known/calculated for each design. Differs significantly per case!

Redesign : Slimstyle bulb replacement (for sale in US)

Shredded before selling

Lamp redesign



Redesign example: medical display (Barco)

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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

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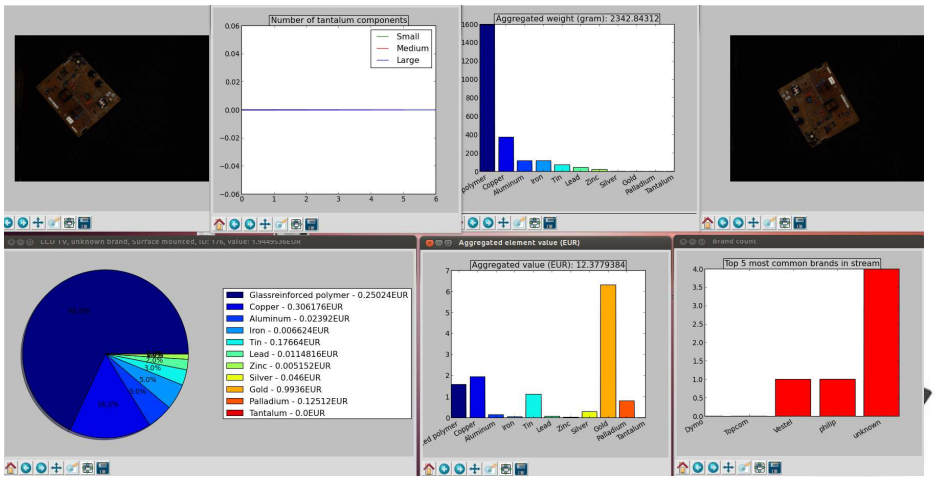
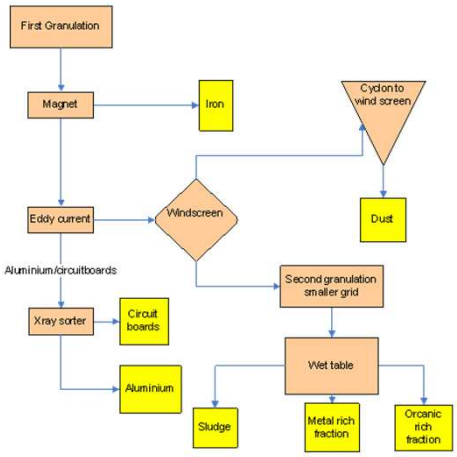
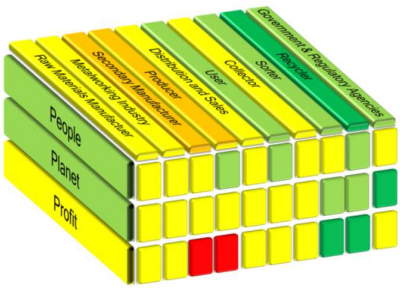
(Refind)



Waste treatment and material recovery (Stena/CIT)



Value chain and policy aspects (TNO)



Effects of mandatory FMDs

Business Interventions
Company level design guideline rules
Recyclability indication integrated in design software
Mandatory Full Material Declarations
Government Regulations
Higher recycling targets
Penalties for not achieving recovery targets
Standardization or specification of design aspects
Producers must recover their own materials
Building a common EU database for product recyclability
EU level design guidelines
Collaboration Interventions
Kick-back fee from recyclers to producers
Designers visit recycling plant
Courses for designers (assembly, disassembly)
Societal Interventions
Pushing for more reporting transparency on both collection and treatment performance

Increase incentive for producer: Circular Economy

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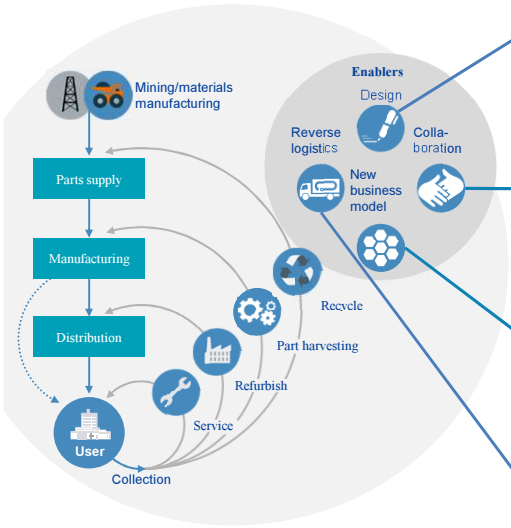

DESIGN for REST VALUE
- Designs that enable multiple life-cycles with minimal loss of value, quality and energy
- Modular design for easy repair & disassembly
- Analyze product status, prognostics
- Design with mono-materials
- Create re-usable platforms

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 circular economy

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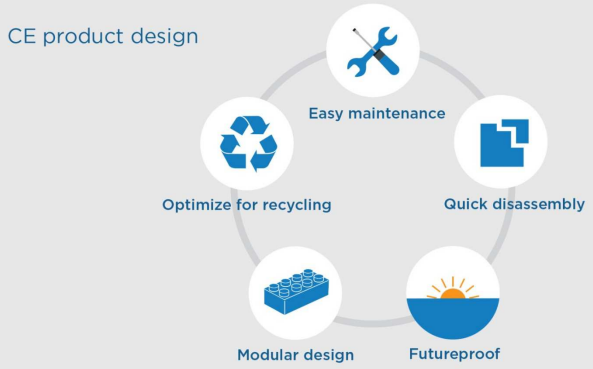
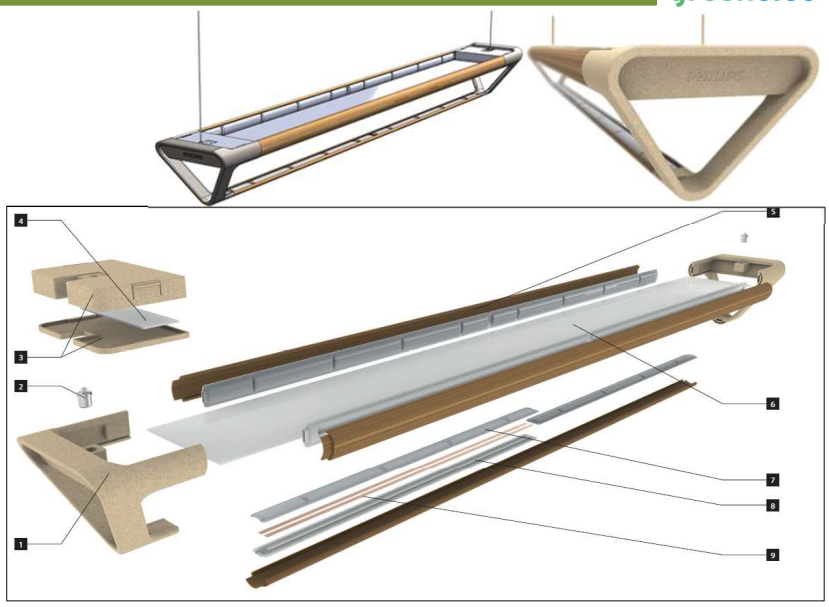


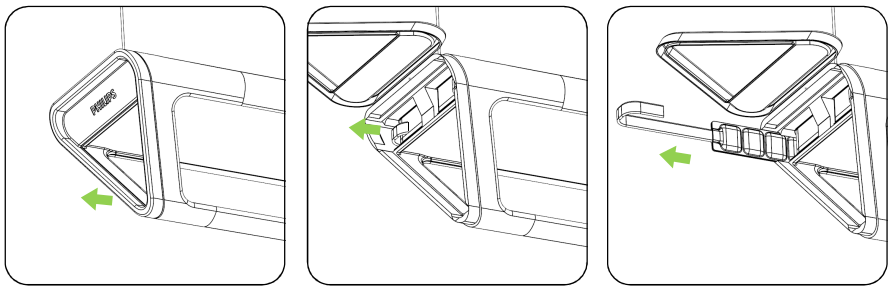
allow easy	maintenance	for optimal performance
by design for	disassembly	
and make it	future proof	for endless performance and adaptability
including	modular	design for remanufacturing
and optimize for	recycling	at end of life

GreenStar: modular luminair



GreenStar design features

- Easy replacement of light engine
- Flip open cover, disconnect, slide out
- Driver unclicks also for easy replacement / upgrades



Exploring new business models

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- 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 CO_2 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

Characteristics

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

"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

Summarizing

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- 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


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