Milieuimpact van elektronica

Hoe bepalen en hoe verminderen?

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imec

With the support of: esa

EDM

D&E EVENT

Het ontwerpen van innovatieve elektronica

Woensdag 19 april 2023
1931 Congrescentrum 's-Hertogenbosch

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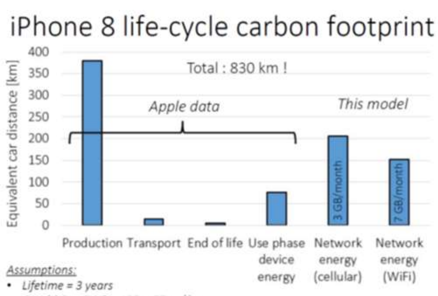
Impact of digitalization



Assumptions:

- *Lifetime = 3 years*
- *Car driving GWP = 120 g CO_2e / km*
- *Carbon footprint expressed in terms of Global Warming Potential (GWG)*
- *Electricity production GWP = 560 g CO_2e / kWh = 160 g CO_2e / MJ (World average)*

Material use:

- 30% of Silver
- 12% of Gold
- 30% of copper
- **80%** of Indium

Source: J.P. Raskin, UCL

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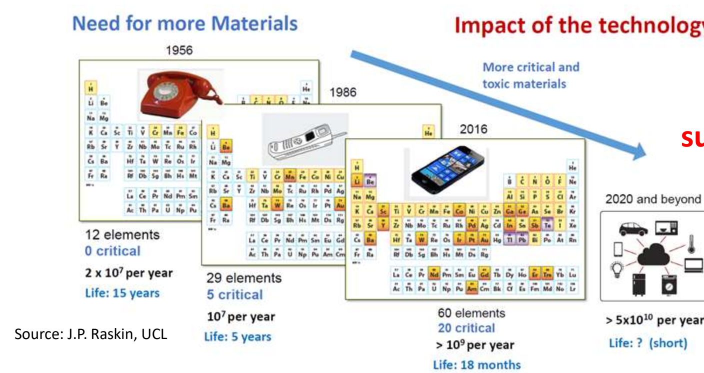
Impact of digitalization



Not sustainable

Source: J.P. Raskin, UCL

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Life Cycle Assessment (LCA) in a nutshell

LCA = LCI + LCIA

for a specific product

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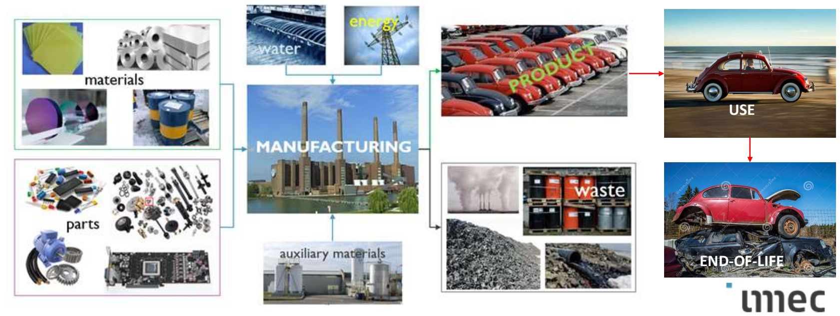
Life Cycle Assessment (LCA) in a nutshell: LCI



Life Cycle Inventory (LCI):

"Compilation and quantification of inputs and outputs for a product" (ISO)

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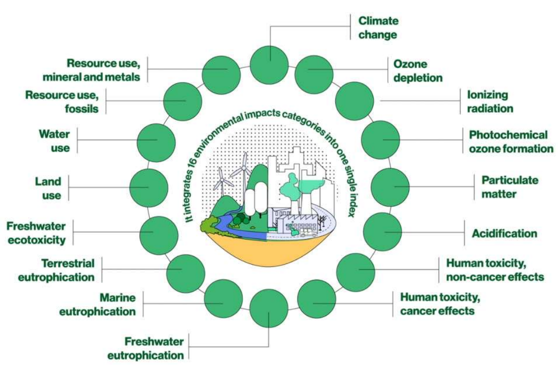
Life Cycle Assessment (LCA) in a nutshell: LCIA



Life Cycle Impact Assessment (LCIA):

"type and extent of environmental impacts of LCI elements"

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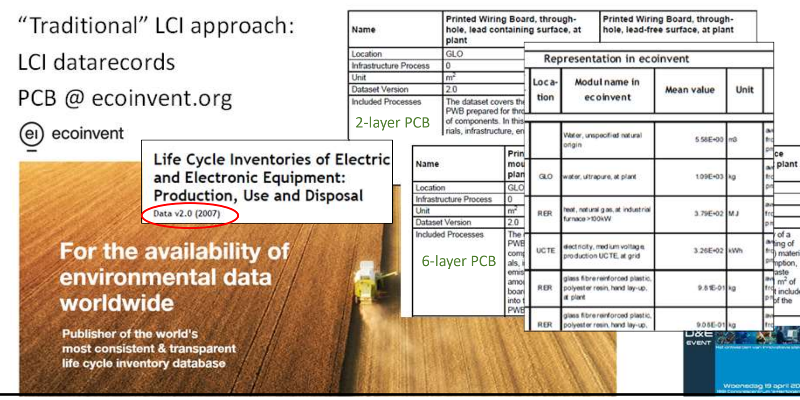
LCI challenge for electronics manufacturing

"Traditional" LCI approach:

LCI datarecords

PCB @ ecoinvent.org



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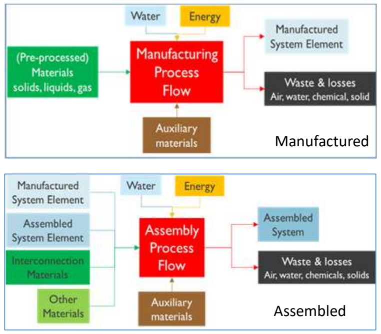
LCI challenge for electronics manufacturing



- Manufactured electronic elements (IC-dies, PCB, ceramic capacitors, film resistors...) may contain a **wide variety of materials** and vary **orders of magnitude** in size and weight even if they belong to the same category.
- The same is true for assembled electronic elements (Packaged ICs, PBA...).

→ *Accurate LCI* ***cannot*** *be based on an "average" LCI dataset scaled by weight, area, et al.*

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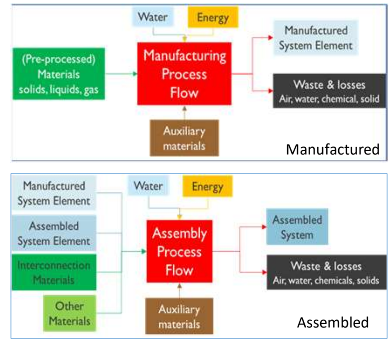
LCI challenge for electronics manufacturing



→LCI must be based on system element design and its manufacturing and assembly processes.

- Design determines what needs to be where in what amounts, in the system element being manufactured/assembled.
- Process flow determines the **LCI parameters** {base materials}, {auxiliary materials}, energy, water and {waste}.

→***Parametric LCI:***

LCI{design/manuf./assembly parameters}

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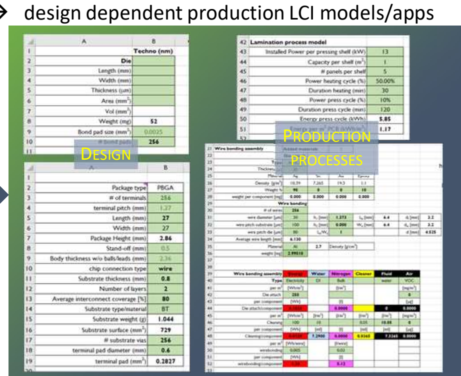
LCI paradigm shift: parametric LCI

From static LCI datarecords → to → design dependent production LCI models/apps

Tab. 3.12 ecoinvent meta information for the "integrated circuit, logic type" dataset

Name	integrated circuit, IC, logic type, at plant
Location	GLO
Infrastructure Process	0
Unit	kg
Dataset Version	2.0
Included Processes	Describes all the processes required to produce a logic type microchip. Included are 'die separation', 'encapsulation', 'die attachment', 'lead bonding', 'plating', and 'marking'. These operations are represented by the material input of glass epoxy, metals, epoxy resin, doped silicon, glue, gold (wires) etc. and the assembly process energy used. The required infrastructure, and the ship, train and road transport are also inventoried. Calculated for 1 kg of packaged logic IC.
Amount	1
Local Name	Integrierte Schaltung, IC, Logik-, ab Werk
Synonyms	Microchip//Microcircuit//Computer chip//Silicon chip//Chip
General Comment	This dataset can be applied to describe the entire production of a logic type integrated circuit. The included wafer fabrication data refers to a 200-mm wafer for a 32 MB DRAM chip, whereas the chip packaging data describes the material contents (in percent) of a plastic ball grid array package (PBGA) microchip (years 2002 to 2004).
Start Date	2000
End Date	2006
Data valid for entire period	1
Geography Text	The data is based on two semiconductor companies in the USA and Western Europe representing international standard.
Technology Text	This dataset describes the chip packaging technology with the typical operation classes die separation, encapsulation, die attachment, lead bonding, plating and marking (inventoried only in form of consumed energy) for a logic-type microchip.
Representativeness	unknown
Production Volume	unknown
Sampling Procedure	Manufacturer information and "chemical content" publications by companies.
Extrapolations	see Geography and Technology
Uncertainty Adjustments	see Geography and Technology



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LCI paradigm shift: parametric LCI

ESA Green eSpace:

- PCB manufacturing , Electronic Assembly, IC packaging

https://www.imec-int.com/en/expertise/cmos-advanced/sustainable-semiconductor-technologies-and-systems-ssts

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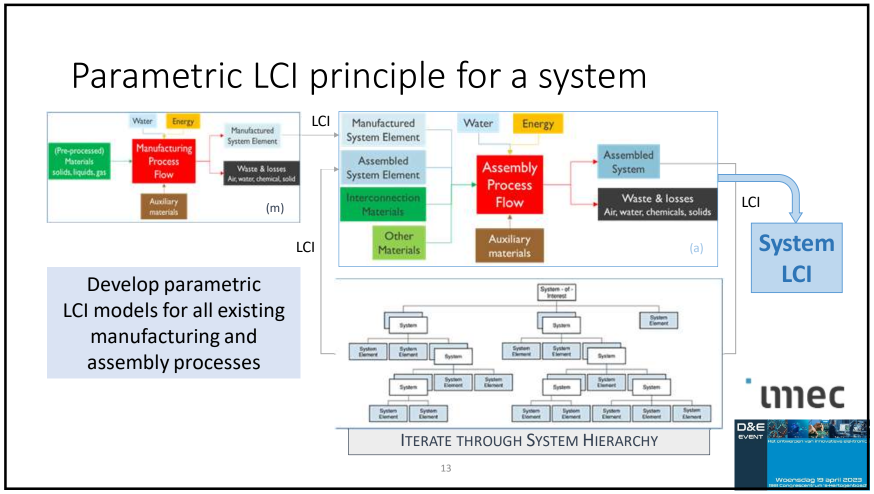

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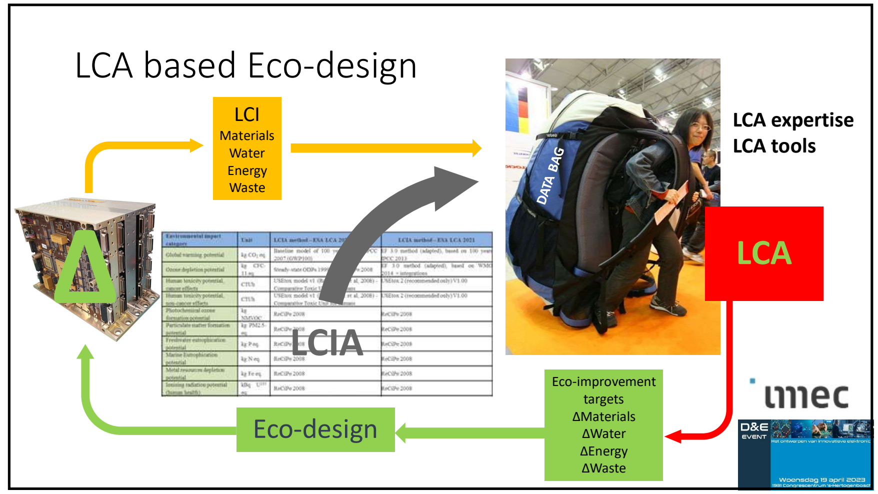

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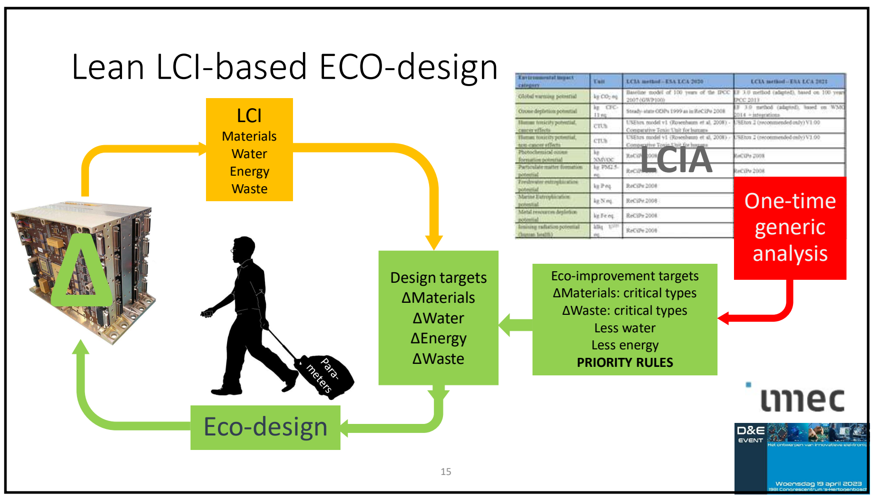

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Lean LCI-based eco-design example

Product out of RoHS scope: **SnPb or lead-free soldering?**

LCIA based one-time hot-spot analysis and priority setting

- 100% take back → no WEEE ending up in environment
  → Pb in waste is not an environmental issue.
- Environmental impact criteria:
  - Ecological impact
  - Energy and greenhouse gasses (CO_2eq)
  - Materials: Resource depletion

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Lean LCI-based eco-design: SnPb vs. SAC

How to compare such different elements?

Express all LCI/LCIA parameters in terms of copper.

Element	Gobal Production 2008 (kTonnes)	Ecopoints per year MPt/yr	Ecopoints/ year/kg Pt/yr/kg	Ecopoints per year [# Cueq]	Ecopoints/ year [gCueq/item]	Embodied Energy [MJ/kg]	Embodied Energy [kWh/kg]	Embodied Energy [# Cueq]	Embodied Energy [gCueq/item]	CO2,eq (GWP) [kg/kg]	CO2,eq (GWP) [# Cueq]	CO2,eq (GWP) [gCueq/item]	ADP [kgSbeq/kg]	ADP [# Cueq]	ADP [gCueq/item]
Aluminum	39590	20000	0.51	0.1	0.00	210	58.33	3.5	0.00	13	3.5	0.00	4.2E-08	0.00	0.00
Copper	17660	150000	8.49	1.0	41.87	60	16.67	1.0	41.87	3.7	1.0	41.87	0.027	1.00	41.87
Gold	2.276	30000	13181.02	1551.8	0.00	250000	69444.44	4166.7	0.00	15000	4054.1	0.00	1500	55555.56	0.00
Lead	8065	5000	0.62	0.1	0.24	27	7.50	0.5	1.50	1.9	0.5	1.72	0.019	0.70	2.35
Nickel	735.3	7000	9.52	1.1	0.00	170	47.22	2.8	0.00	11	3.0	0.00	0.0012	0.04	0.00
Platinum	0.1926	1100	5711.32	672.4	0.00	270000	75000.00	4500.0	0.00	15000	4054.1	0.00	1000	37037.04	0.00
Silicon (wafer)				0.0	0.00	7860	2183.33	131.0	0.00	2100	567.6	0.00	1.3E-09	0.00	0.00
Silver	21.35	7000	327.87	38.6	0.00	1500	416.67	25.0	0.00	100	27.0	0.00	10	370.37	0.00
Tantalum	*27*	25	0.93	0.1	0.00	4300	1194.44	71.7	0.00	260	70.3	0.00	0.0016	0.06	0.00
Tin	333.4	900	2.70	0.3	1.78	230	63.89	3.8	21.47	13	3.5	19.68	0.074	2.74	15.35
				Ecological impact	43.90			Energy	64.84		CO2 eq	63.26		resource depletion	59.57

ADP: Abiotic Depletion Potential – use of fossil minerals and raw materials

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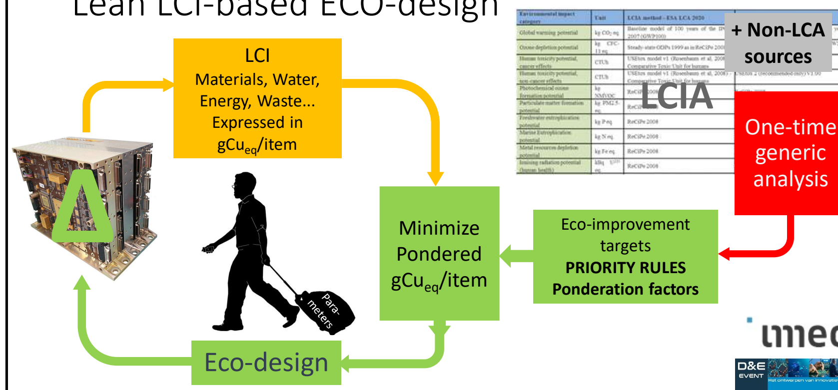
Lean LCI-based ECO-design



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Lean LCI-based eco-design: SnPb vs. SAC

	Ecological impact	Energy	CO2 eq	water	Resource Depletion	Supply Risk SR	Economic Impact EI	SR & EI	Total check	
Ponderation (%)	25	25	25	0	25	0	0	0	100.00	
Material [g Cueq]	43.90	64.84	63.26	244.24	59.57	55.06	48.83	48.83		
Energy [g Cueq]		144.06	178.4527							
Water [g Cueq]		0	0	0						
Sum [g Cueq]	43.90	208.90	241.72	244.24	59.57	55.06	48.83	48.83		
Eco-score										
Pondered [g Cueq]	10.97	52.23	60.43	0	14.89	0	0	0	**138.521**	per item
									277.042	per kg
SnPb soldered – HASL SnPb (materials only)									**2770.42**	per m^2

	Ecological impact	Energy	CO2 eq	water	Resource Depletion	Supply Risk SR	Economic Impact EI	SR & EI	Total check	
Ponderation (%)	25	25	25	0	25	0	0	0	100.00	
Material [g Cueq]	75.06	134.80	131.39	369.11	924.17	58.73	48.13	48.13		
Energy [g Cueq]		157.86	195.55							
Water [g Cueq]		0	0	0						
Sum [g Cueq]	75.06	292.66	326.93	369.11	924.17	58.73	48.13	48.13		
Eco-score										
Pondered [g Cueq]	18.76	73.17	81.73	0	231.04	0	0	0	**404.705**	per item
									809.41	per kg
SAC soldered – ENIG NiAu (materials only)									**8094.1**	per m^2

Compare design options by comparing total equivalent Cu weight.

~3x higher NEGATIVE impact for "green" Option.

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Lean LCI-based ECO-design

Selection of critical environmental factors and priority setting determine LCI and Eco-design.

- RoHS: sole focus on human toxicity of WEEE (Pb, Hg, Cd, Cr^{6+}...)
- Eco-design case: ecology, energy, climate and natural resources
  - Lead-free: uses more metals with high environmental impact.
    - 50% more Sn (0.3-3.8Cu_{eq}) replacing Pb (0.1-0.5Cu_{eq})
    - Noble metals: Ag (25 - 370 Cu_{eq}) and Au (1550 – 55555 Cu_{eq}!)
  - 15-20% more energy consumption in soldering due to 25-30°C higher T.
  - Ag is aquatoxic.

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Lean LCI-based ECO-design

"Everything should be done as simple as possible but not simpler"
(A. Einstein)

- Focusing on a single impact factor may be counter productive.
- Environmental impact is complex.
  Multiple factors need to be taken into account.
- Relevant impact factors depend on the product's life cycle.
- Do the math and let the numbers speak.
- Always acknowledge assumptions and uncertainties.

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Acknowledgement

ESA project "Life Cycle Assessment of Green Electronics for Space" (Green eSpace) (contract nr. 4000133313/21/NL/AS)

https://www.esa.int/Space_Safety/Clean_Space

https://indico.esa.int/event/321/contributions/6337/attachments/4384/6608/CSID2021_Green-eSpace%2520project%2520overview.pdf

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Dank voor uw aandacht

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