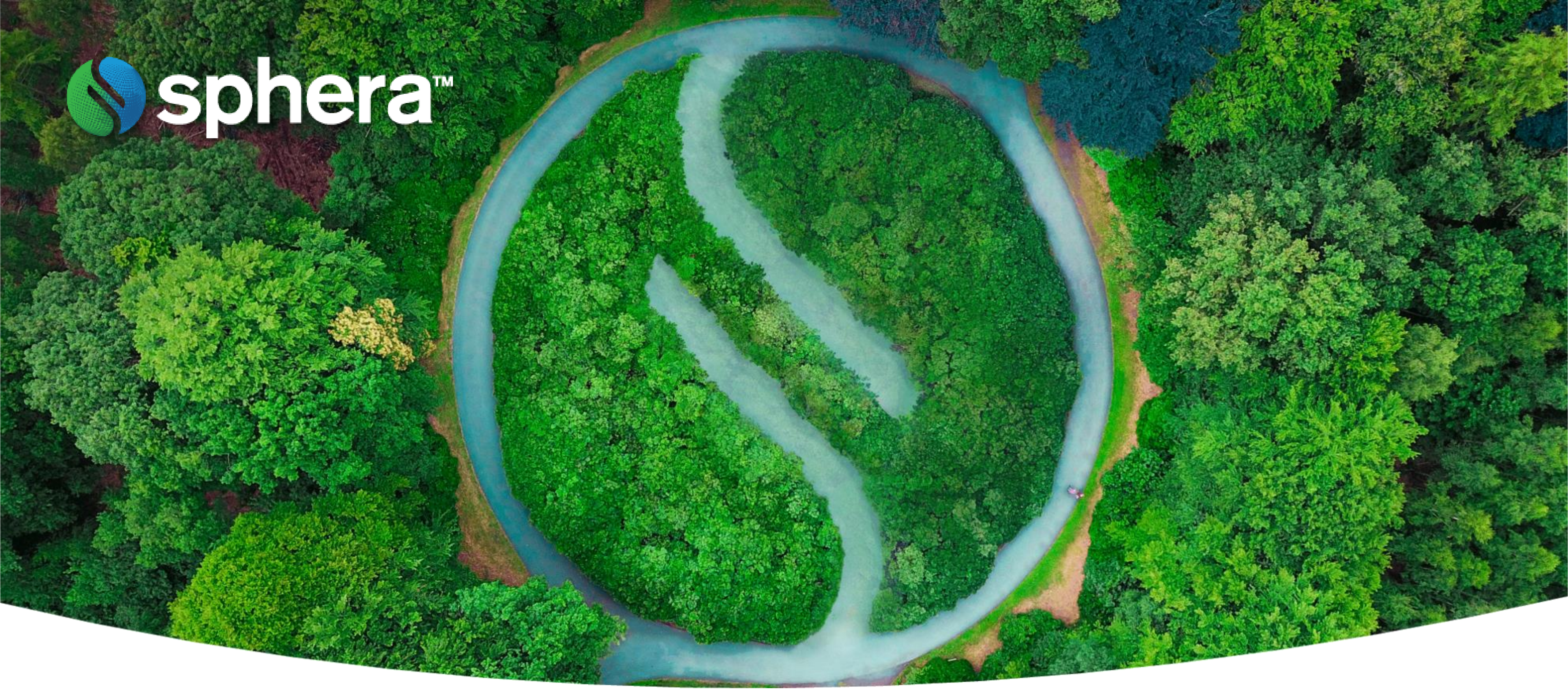

# Electronics in LCA and Life Cycle Thinking of Electronics, Hot Spots and Lessons (to be) Learned

9.9.2020, SICT 2020, Louvain-la-Neuve, Belgium

# Introduction

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Sphera is the leading global provider of Integrated Risk Management software and information services with a focus on **Environment, Health, Safety & Sustainability, Operational Risk** and **Product Stewardship.**

Environment, Health, Safety & Sustainability

Operational Risk Management

Product Stewardship

# Our Mission

To create **a safer, more sustainable** & **productive world**.

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# Operationalize, scale, & optimize Integrated Risk Management

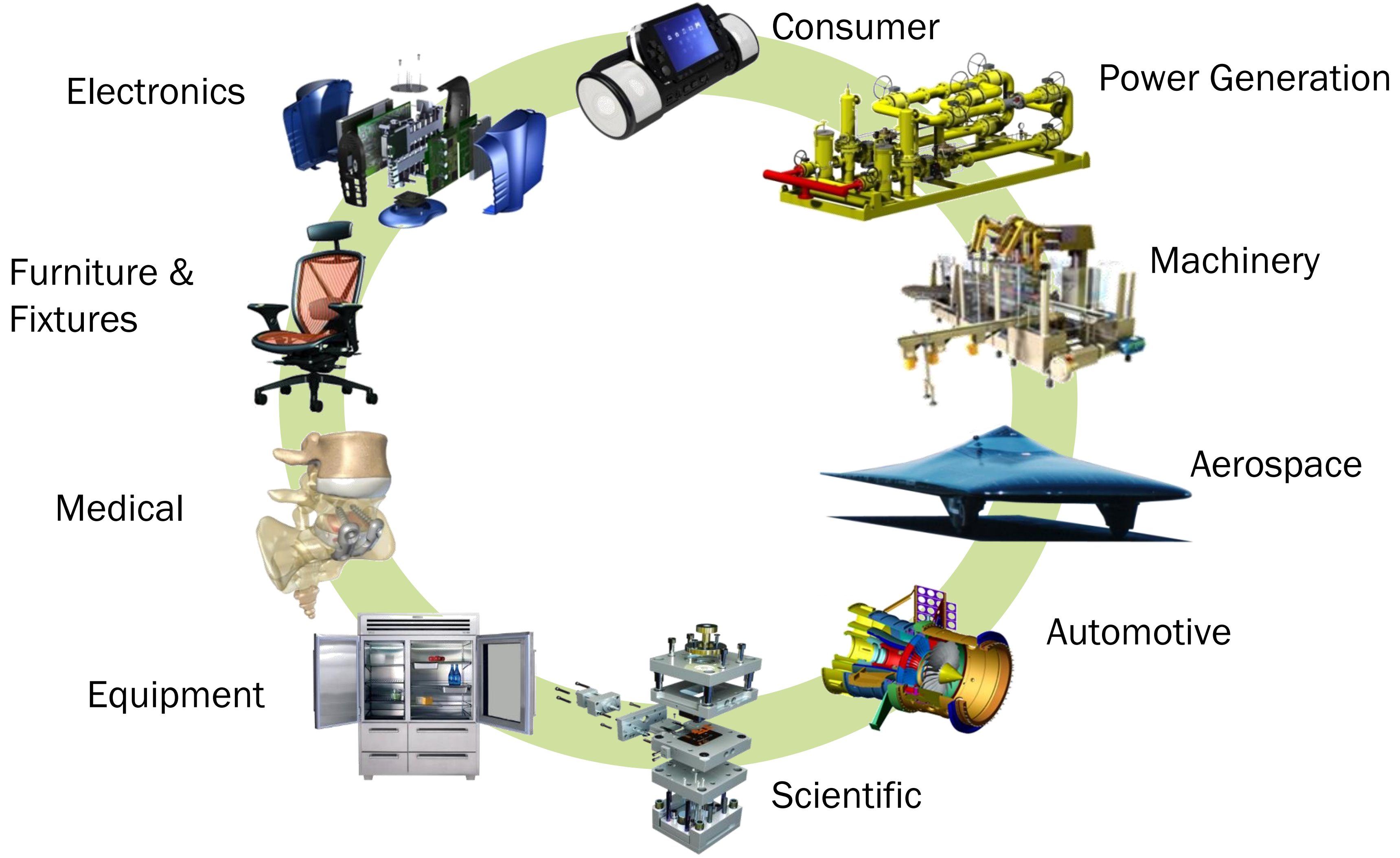
with our purpose-built solutions supported by information, innovation & insights

# Setting the Scene

# Life Cycle Thinking (LCT)

# What are typical Products of IT and Electronics

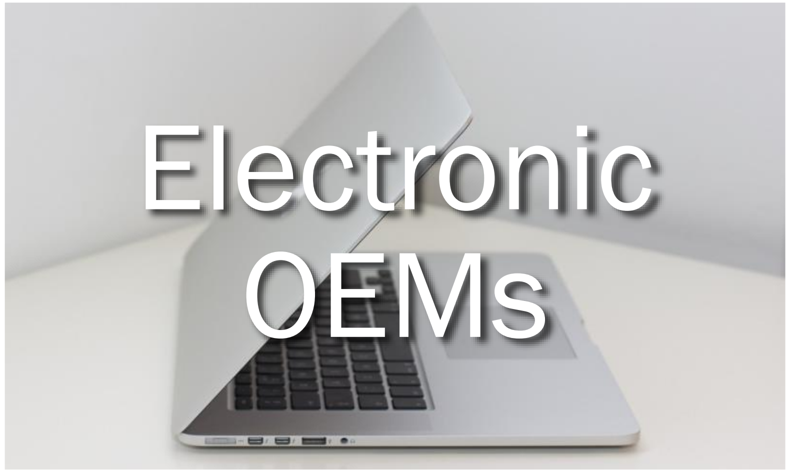
Examples



# Where and What is IT and Electronics

Examples



# LCT of IT/ICT and the Internet

## Examining the Sustainability of the Internet

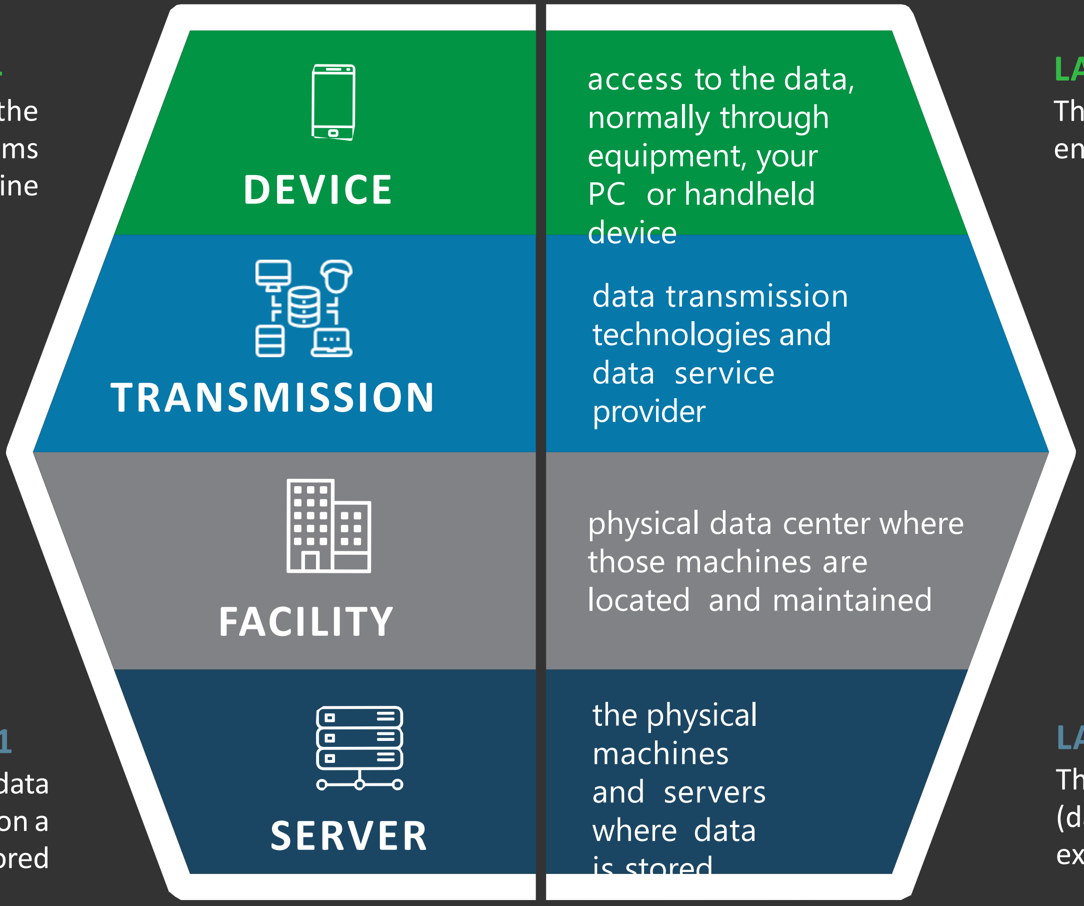
Industrial Example

**LAYER 4**
The device used by the person who performs maintenance on a machine

**LAYER 3**
Transmission of the data to the service user

**LAYER 2**
The facility where servers are stored and operated

**LAYER 1**
The server on which data (originating from sensors on a machine) is stored




Social Networking Example

**LAYER 4**
The device(s) used by the end consumer

**LAYER 3**
The service of sharing social experiences with the world and transmitting the video as data to end users' devices

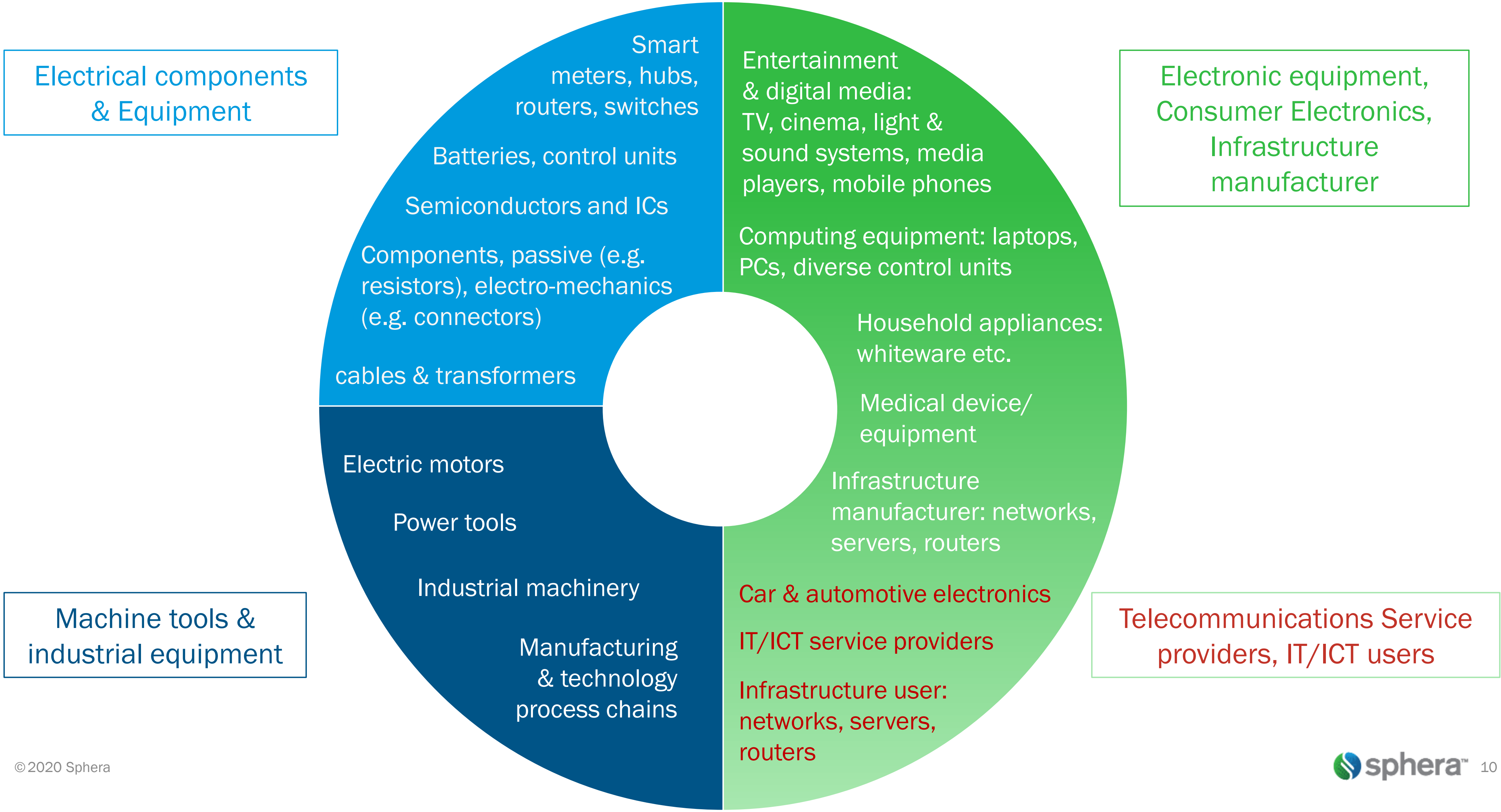
**LAYER 2**
The facility where servers are stored and operated

**LAYER 1**
The server on which the video (data) you created for upload exists

Source: [https://sphera.com/blog/how-green-is-the-internet/](https://sphera.com/blog/how-green-is-the-internet/)

# Sectors and Supply Chain of IT and Electronics

## Examples for a structural approach

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# Drivers for LCT and LCA of Electronics

## Usual argumentation, dominated by efficiency and reduction targets

- Information and Communications Technology (ICT) responsible for 2.6% of global GWP emissions*

- Benefits of performing LCAs on electronics and electronic products
  - Getting beyond compliance management
  - Shift conversation from firefighting to scientific understanding of sustainability
  - Evaluating design trade-offs:
    - New power-saving technologies with greater hardware complexity
    - Move to more integrated, compact, and complex hardware systems
    - Digitizing conventional services
  - Electronics have significant impacts across entire life cycle
  - Area for innovation and differentiation in product design and product management
  - Balancing footprint and handprint (benefits from applying ICT for abatement in other sectors)

*Source: SMART 2020, IEA, BCG analysis

# Drivers for LCT, LCA and Circular Economy

## Future argumentation: towards zero carbon - European Green Deal for a carbon free Europe by 2050

- Companies, politics and economic regions require carbon neutrality
  - European Green Deal of the EC
  - $CO_2$-tax system in Europe
  - VW, BP, Danone, Daimler, Microsoft, Apple claiming to become carbon neutral (including scope 3)
- Zero carbon means zero scope 1, 2 and 3
- Scope 3 includes upstream and downstream (supply chain, logistics, use and EoL)
- Not just energy, but also materials and anything needs to become carbon neutral
  - Avoid
  - Reduce and Capture
  - Offset
- Carbon neutral material is rare
- Circular Economy (CE) is key enabler for carbon neutrality as it can provide carbon neutral materials

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# Aspects of Electronics and LCA

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# Analyzing Electronic Products is Complex

- Manufacturing processes are complex,
- Process steps and details are not common knowledge
- Manufacturing is more process-intensive, less material intensive → impacts are not immediately apparent  by visual inspection (energy & fuels)
- Electronic products have fast innovation cycles and electronic components evolve fast with rather low profit rates
- The complexity of electronic products, both in term of:
  - the sheer number of components

  and
  - the type and size of components

<u>For Example…</u>

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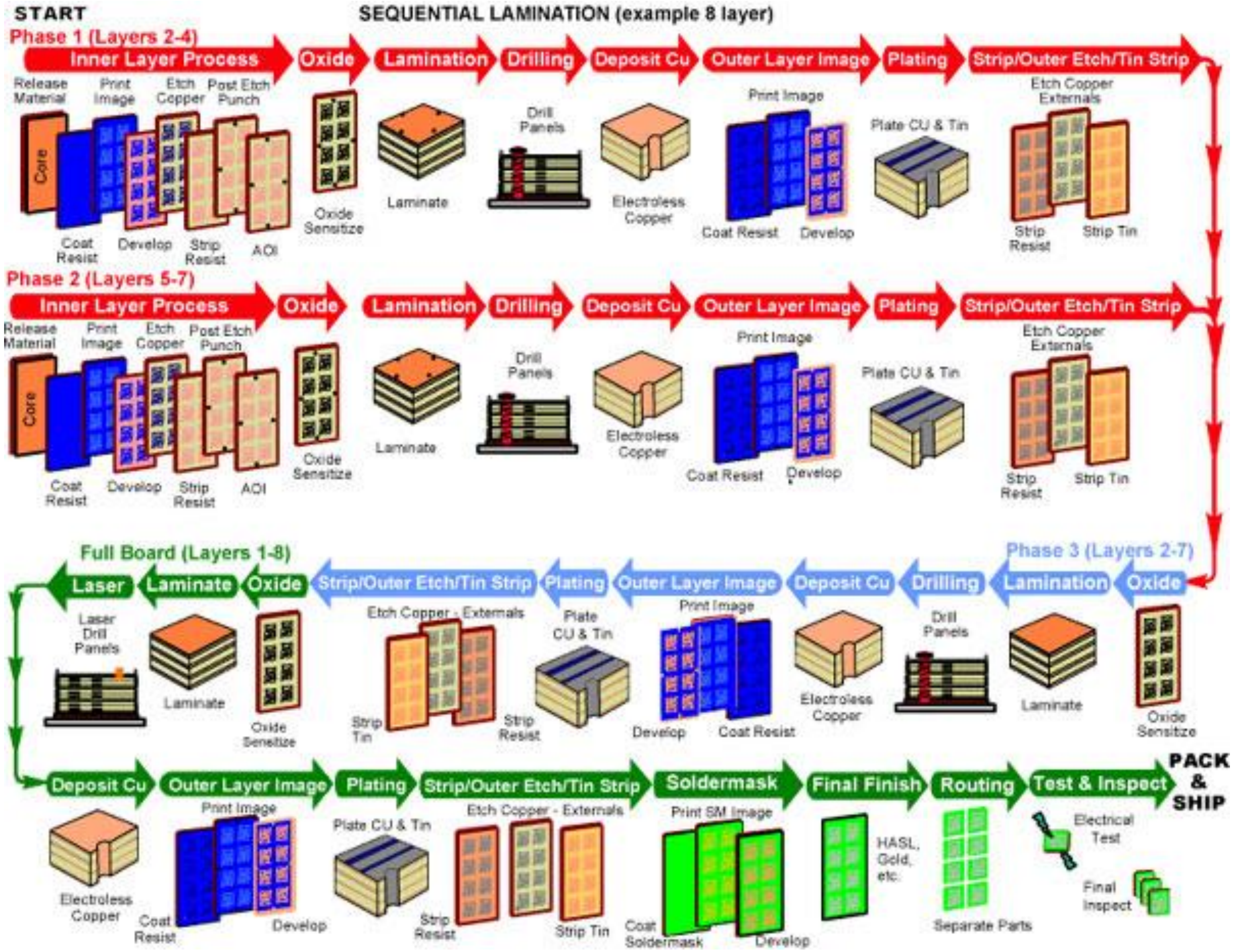
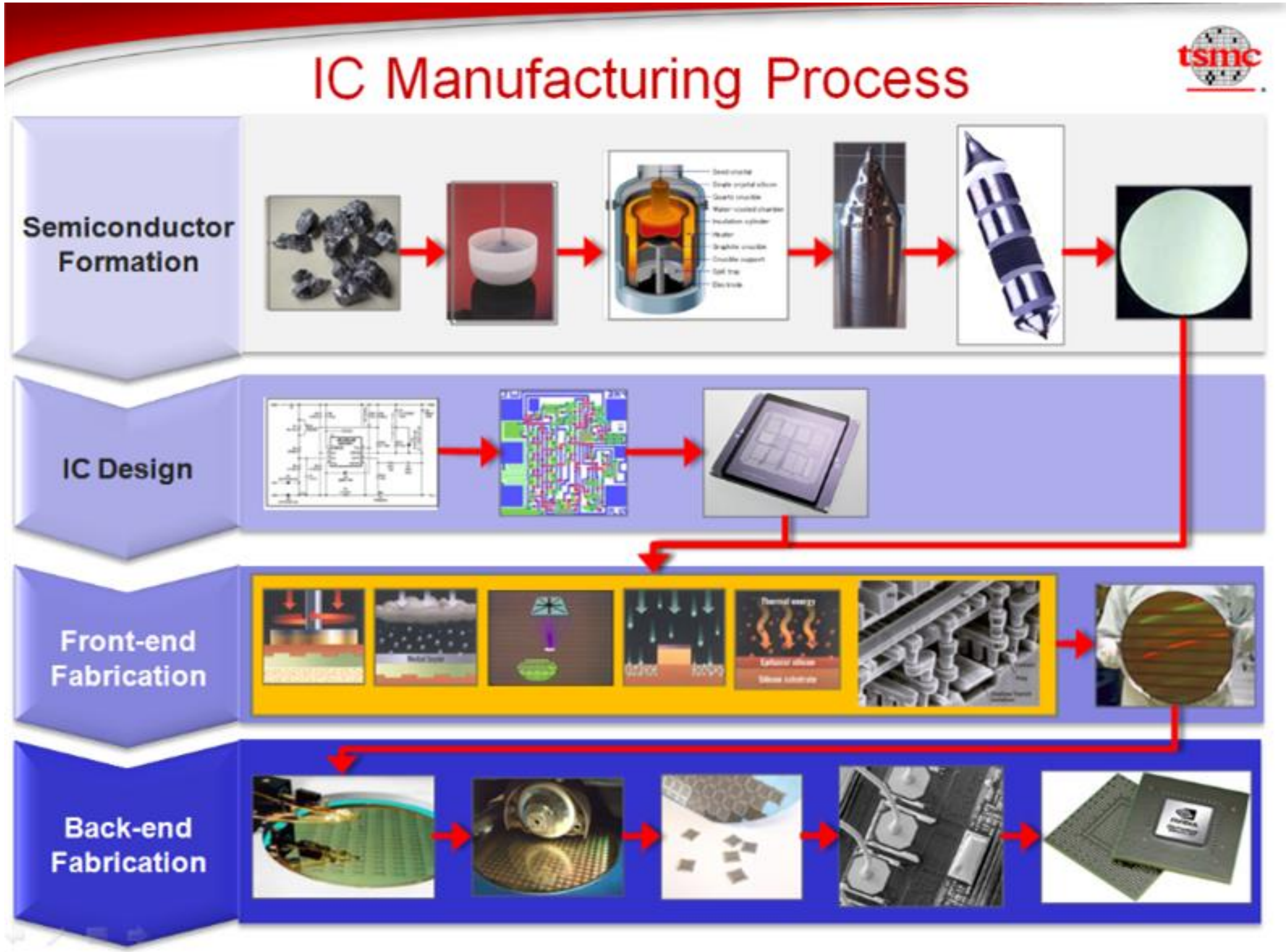
# PCB Manufacturing Process

## Example



# IC/Semiconductor Manufacturing Process

Example




Source: TSMC

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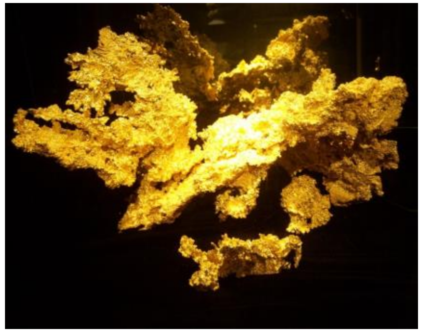
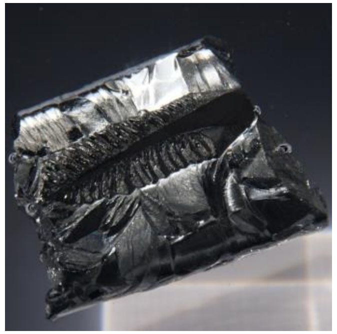
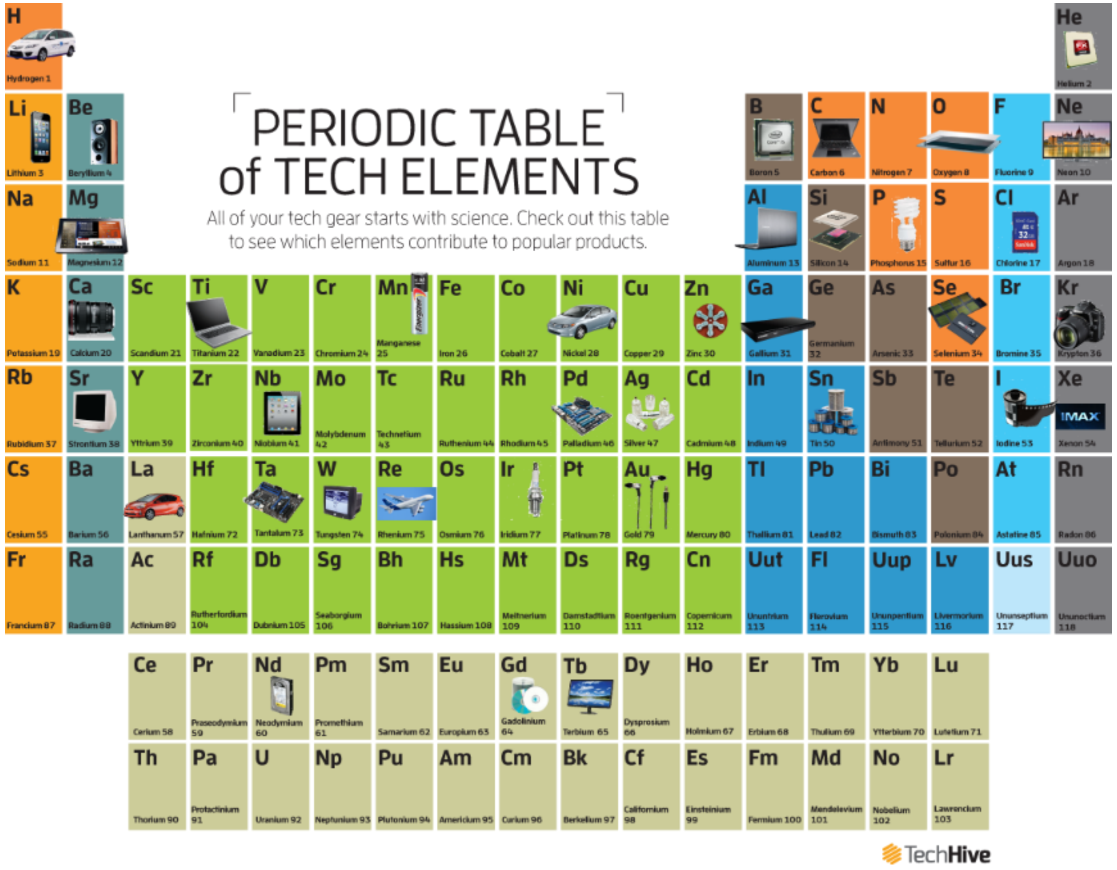
# Electronics refer to almost entire Periodic Table of Elements

- Rare elements → availability issue, substitution issue, resource criticality
- Hazardous substances → awareness issue, substitution issue, health criticality
- Precious metals → cost- and effort-intensive, economic and resource criticality





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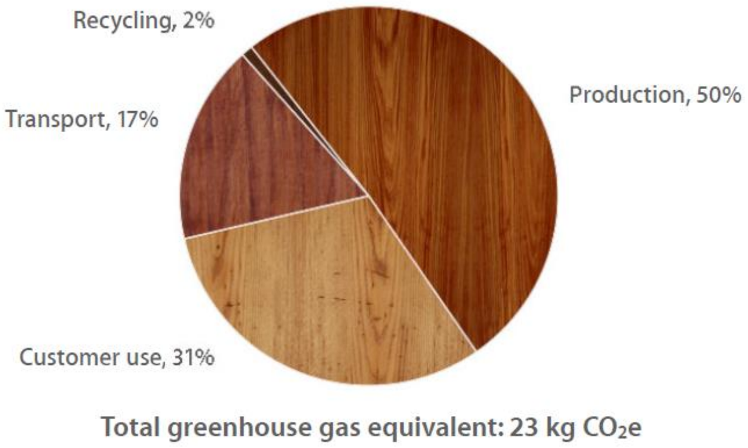
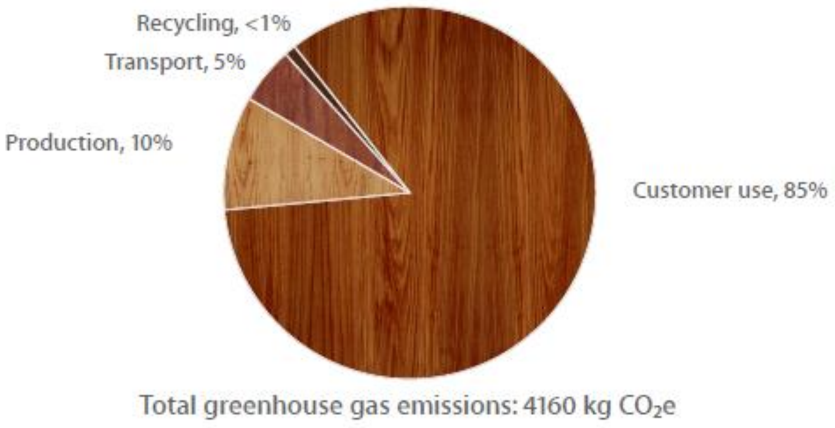
# Use-phase impacts can be significant…

## But manufacture can be significant as well …

- Power consumption can vary greatly depending on state (high use, standby, “off”)
- Function dictates structure: since range of application is extremely wide, the range of products is also very wide → there is no average electronic product!
- Share of use phase dependent on product:
  - iPod Classic: Use phase <40% of impacts
  - Xserve server: Use phase >80% of impacts
- Eco-design strategy must be informed by life cycle perspective




Source: Apple homepage 2010

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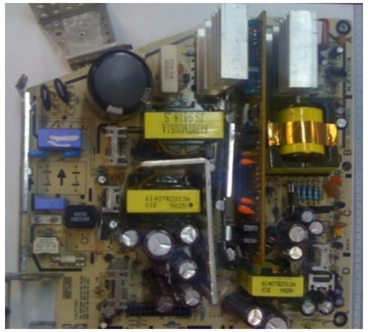
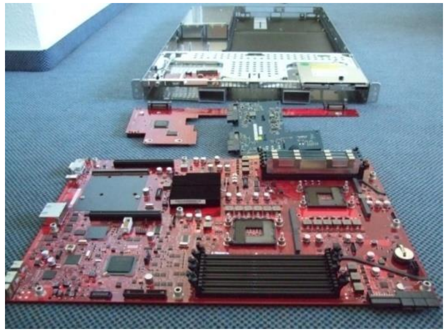
# Electronic products are difficult to classify

- Difference between electronics and electronic product
- Difference between electronics, mechanics, electro-mechanics
- To specify them the minimum information must contain:
  - Size (Area) and type of substrate
  - Number and type of ICs
  - Components with large mass (ring core coils, transformers, large capacitors, transistors etc.)
  - Everything that is precious
- Electronic product assemblies are complex, both in term of:
  - the sheer number of components
  - the type and size of components


# LCA Modelling of Electronic Products

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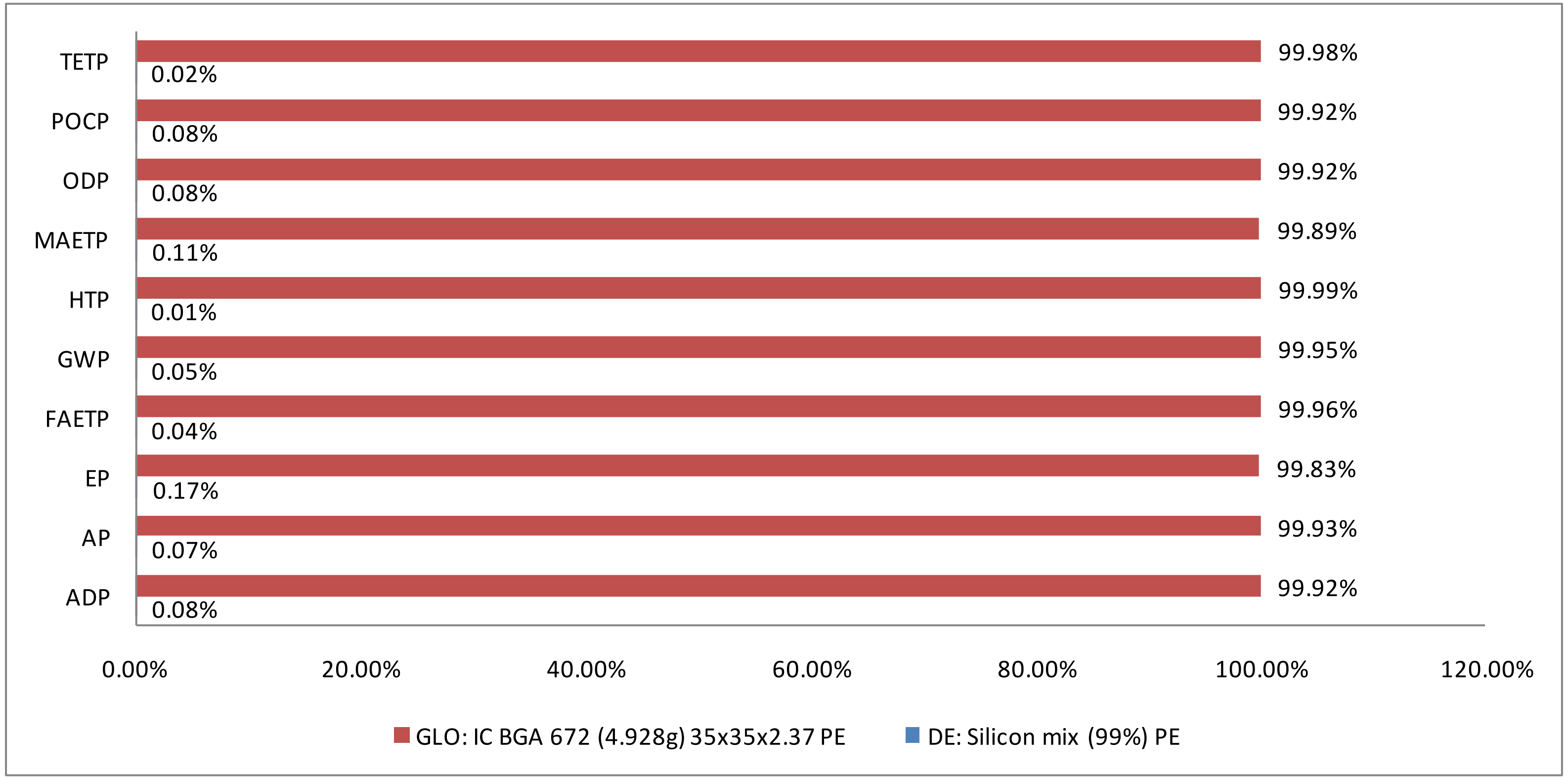
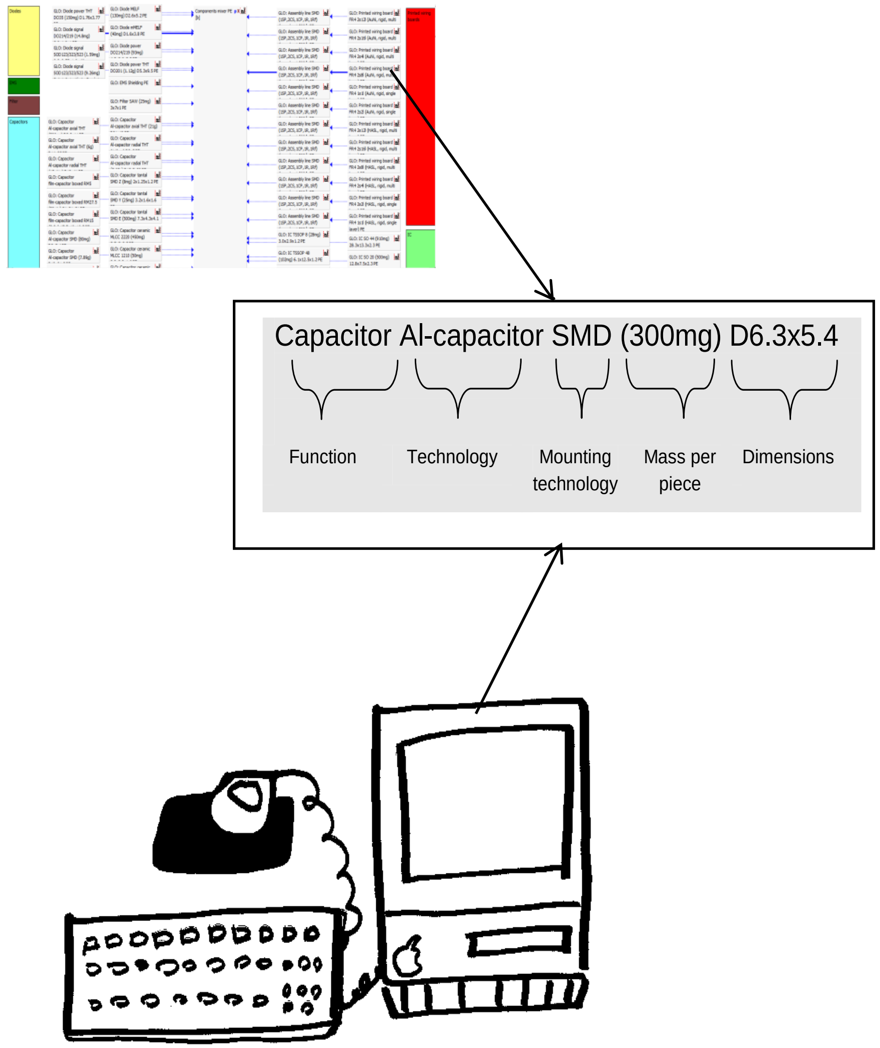
# Comparison of impact between:
# 1 piece of IC vs. same mass of silicon (metal grade)

- What do you think?
  - Material composition is not the only determining factor.
  - Expect to see manufacturing processes lead to larger impacts associated with IC.

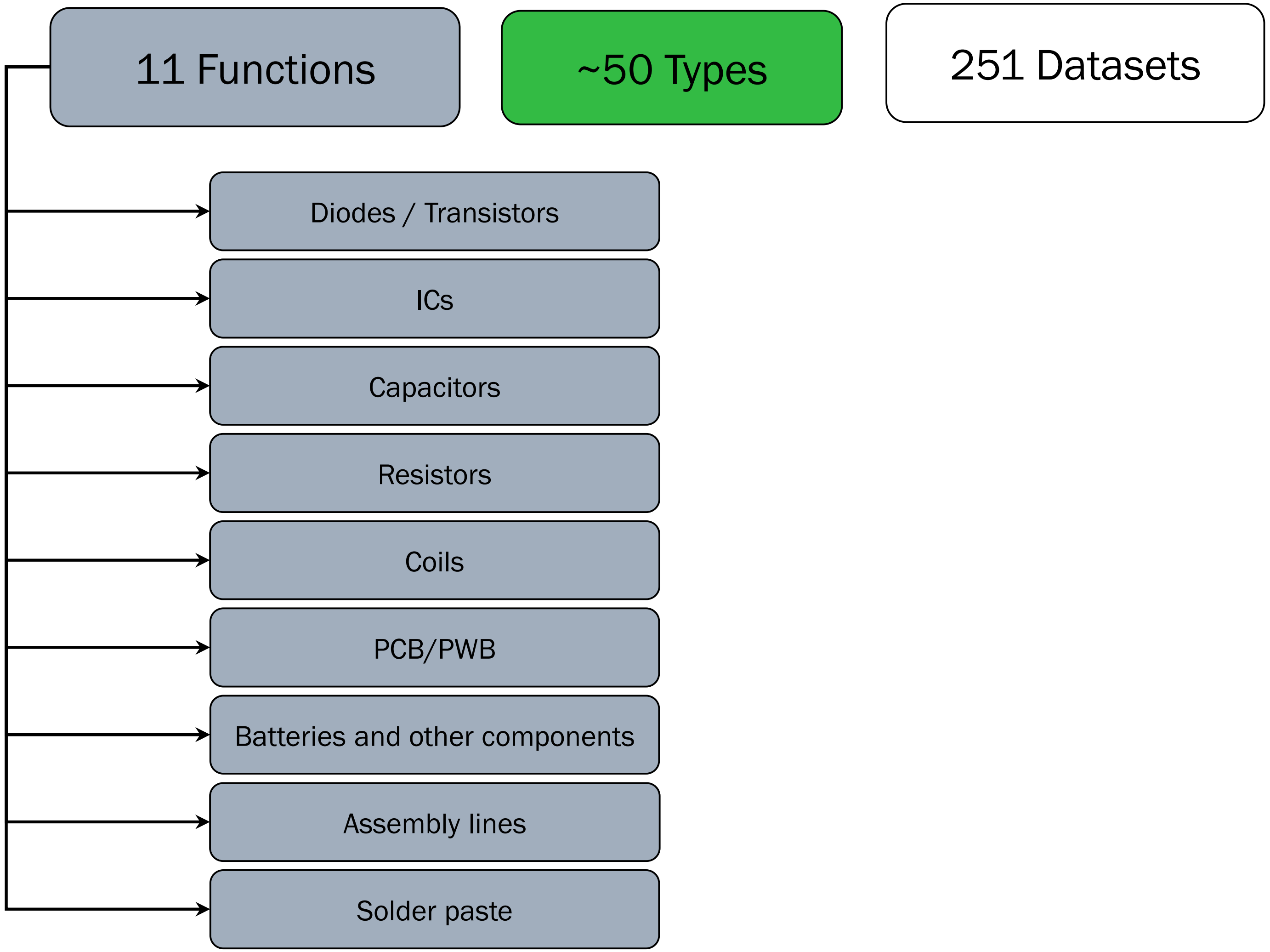


# Modeling electronic products is slightly different from other products

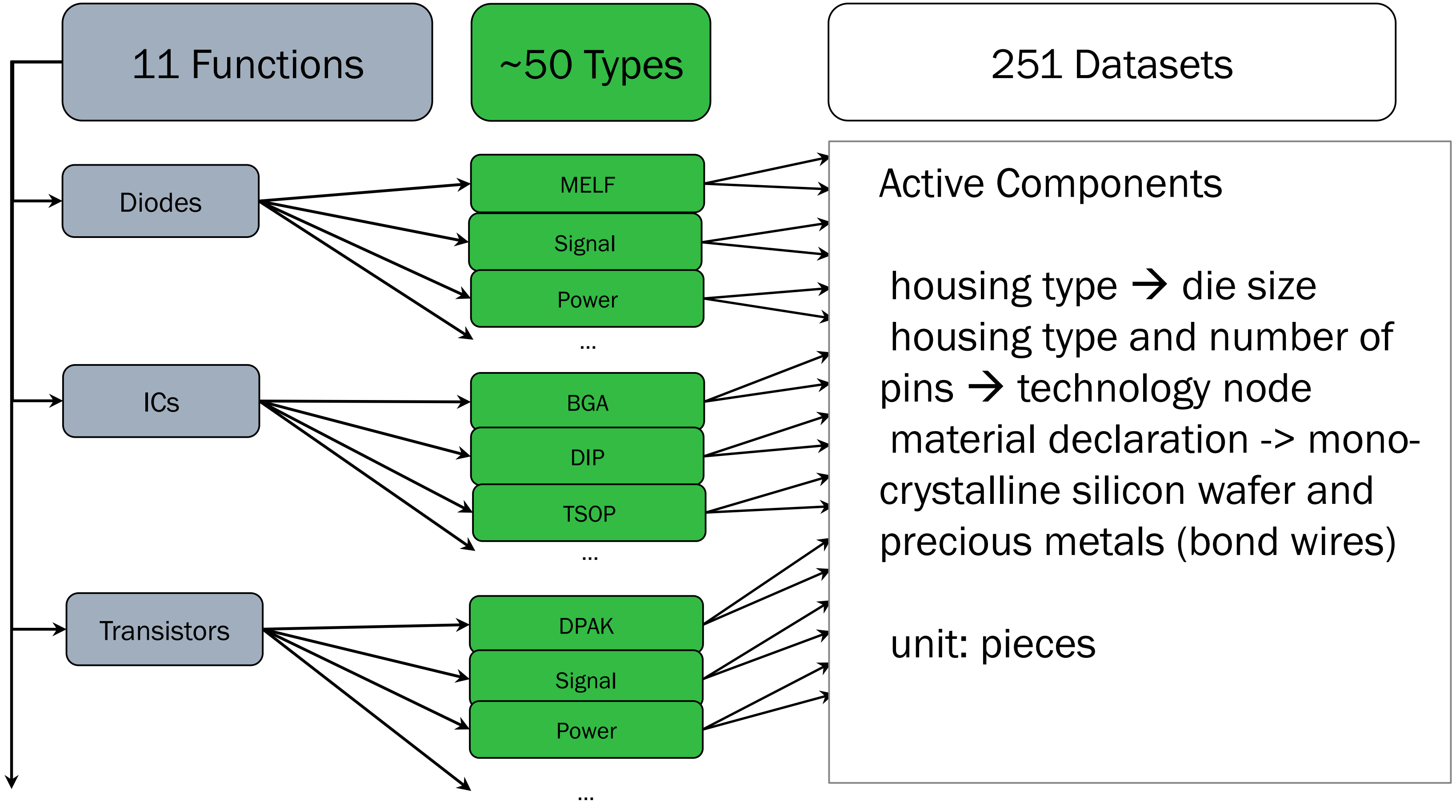
- Components must be described with existing datasets
- Modeling with representative components (>10mio existing component types are represented by 251 datasets) based on size, materials and production processes



# Electronics Database in GaBi



# Active components

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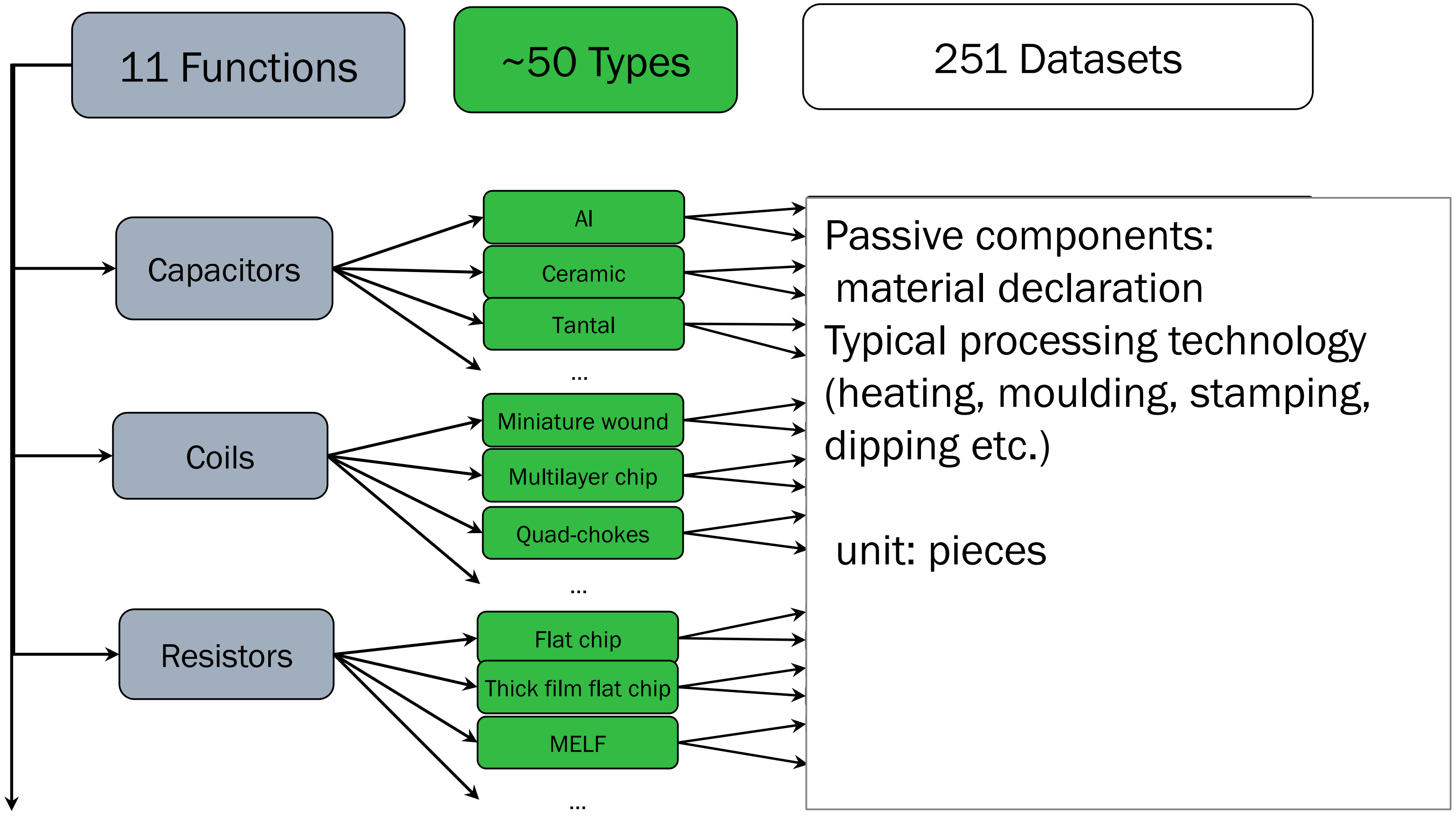
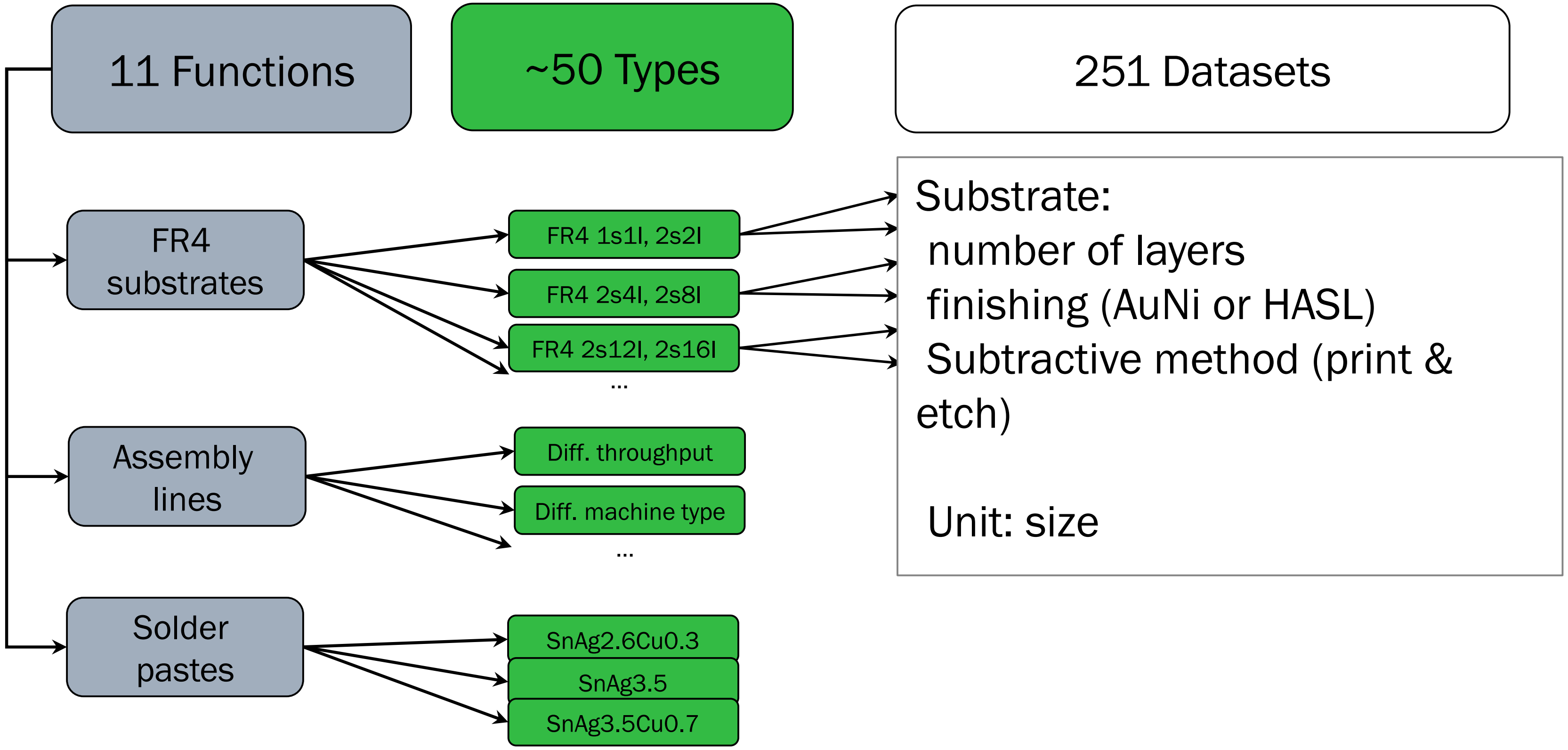
# Passive components



# Other components



# Rules of Thumb in LCAs of electronic products

Use phase dependent on use scenarios

- Power off mode
- Power active mode
- Power sleep mode
- …

Manufacturing

- Mechanics - mass dependent (e.g. housing)
- Electro-mechanics - mass dependent (e.g. cables, connectors)
- Electronics
  - Size of board
  - Size of die (for chips/ICs)
  - Massive components
  - Precious metals (in components, mechanicals, or board)

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# Modeling a Power supply Unit

# Modeling a Power supply Unit

# How to describe the PSU?

- Total mass: 0.872kg
- Mass of plastic housing: 0.15 kg
- Mass of cables: 0.20 kg
- Mass of inlet filter: 0.04kg
- Mass of circuit board (Printed Wiring Board, PWB): 0.482kg
- Area of circuit board (Printed Wiring Board, PWB): 0.0178 m2
- Number and type of electronic components on the PWB
- Mass of connectors with and without gold contacts

| Electronic component | Amount | Unit | Mass |
|---|---|---|---|
| Printed wiring board FR4 2s4l (AuNi) | 0,0178 | m2 | 0,2625224 |
| Ring core coil | 7 | N pieces | 0,154 |
| Capacitor Al-capacitor axial THT (6g) | 6,6 | N pieces | 0,0396 |
| Connector (without Au) | 0,012 | kg | 0,012 |
| Coil quad-chokes (2.5g) | 2,6 | N pieces | 0,0065 |
| Capacitor film-capacitor boxed (3.2g) | 0,9 | N pieces | 0,00288 |
| Transistor (290mg) | 8 | N pieces | 0,00232 |
| Capacitor film-capacitor unboxed (150mg) | 9 | N pieces | 0,00135 |
| Diode power (93mg) | 5,2 | N pieces | 0,0004836 |
| IC SO 8 (80mg) | 4 | N pieces | 0,00032 |
| Resistor flat chip (0.6mg) | 40 | N pieces | 0,000024 |

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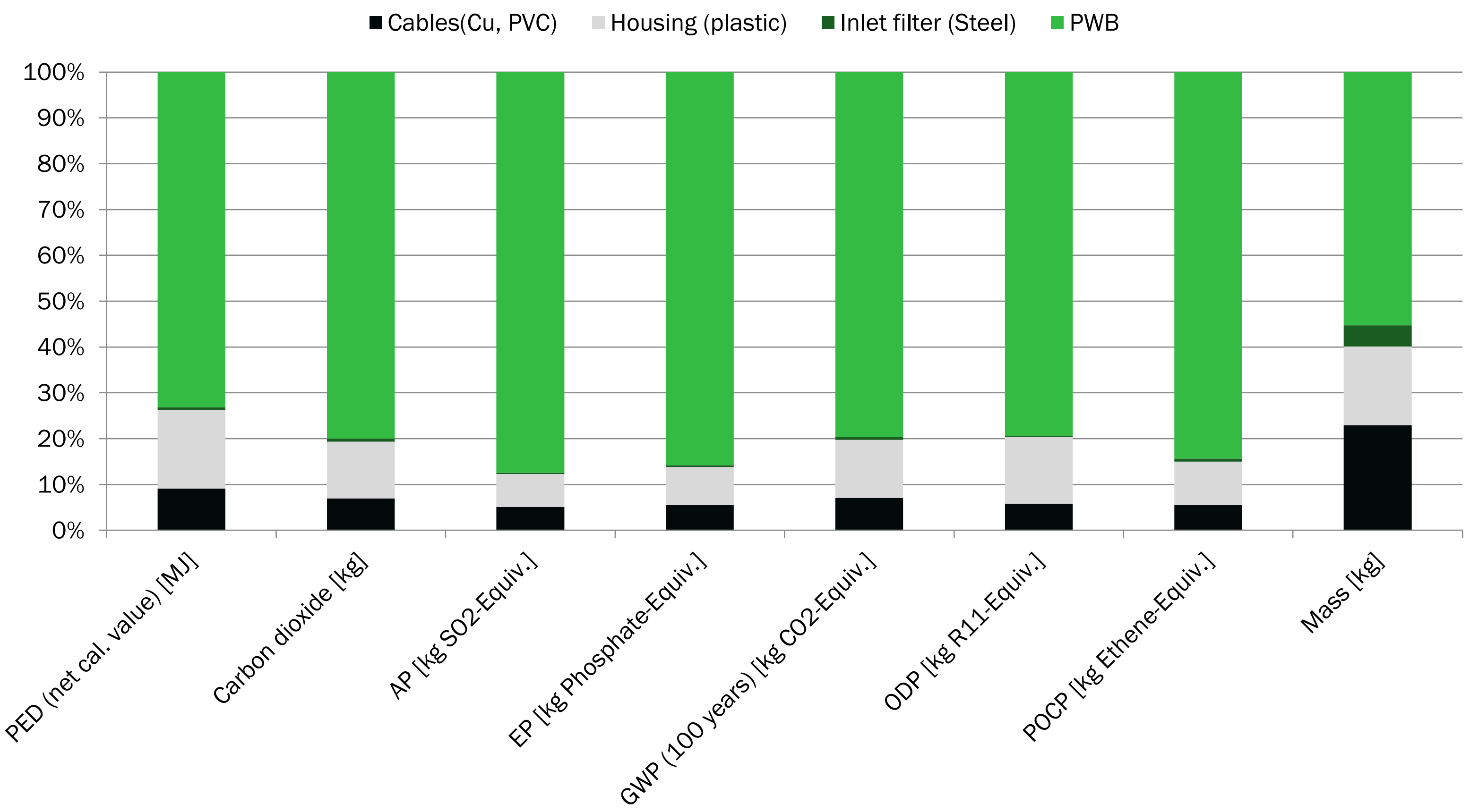
# PSU subcomponent analysis I

- Contribution by the subcomponents to total mass, CO2 emissions, PED and environmental Impact Categories (CML, 2001)
- All impact categories are shown as 100%, thus they are not comparable to one another

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# PSU submodule analysis II

- All environmental impacts are dominated by the impact coming from the populated printed wiring board (PWB)
- The relative contribution of the PWB is considerably higher to any and all impact categories than to the total mass
- The relative contributions of the housing, the inlet filter and the cables are lower to any and all of the impact categories than to the total mass

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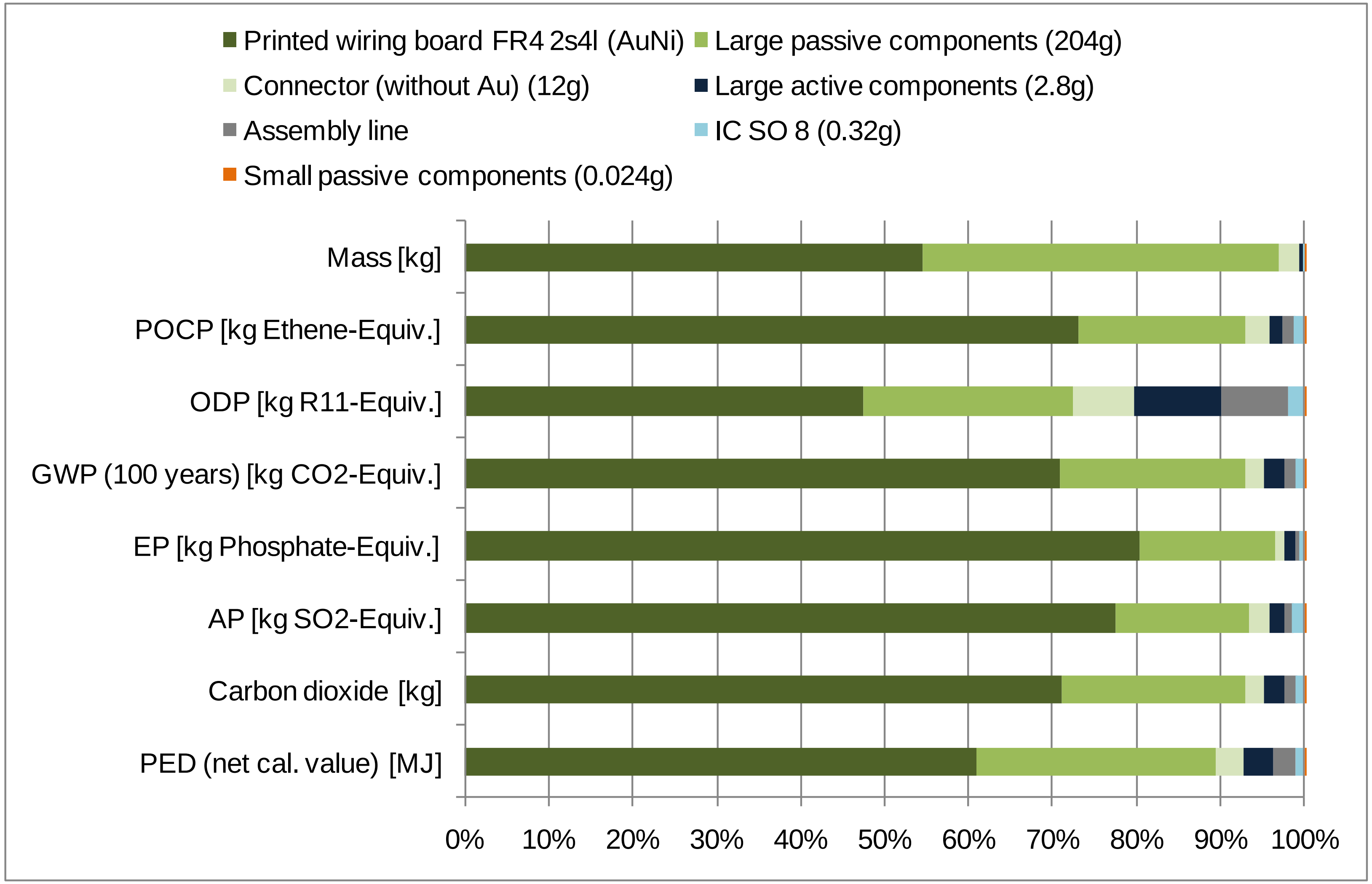
## PWB analysis I

# Electronic components and processes in PWB manufacture



## PWB analysis II

# Environmental “hotspots”

- Substrate: rigid board made of FR4, 2-sided, 4-layer, Gold-Nickel finishing
  - By far the highest environmental impact in all categories
  - Long, multi-step production chain of the PWB itself (per area), upstream production of raw materials mainly from gold (less from nickel, copper, epoxy resin, glass fibres)
- Second largest contribution comes from large passive components (seven ring core coils etc.)
  - Contribution is due predominantly to sheer mass
- Relative to their small mass (10-100 times less than power transistors, connectors, or large capacitors), the contribution of ICs is outstanding: about half of any of those component groups, and twice as much as the diodes of the same mass range
- The assembly process itself needs energy, and contributes to the total, but does not dominate
- Small passive components, such as resistors do not contribute significantly to any impacts

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# Screen, Scope, Scale of IC Models for LCA

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# Screen Scope Scale approach helps to focus sustainability investments on core leverages

**Screen**

Find hotspots and opportunities in your entire value chain

**Scope**

Understand drivers and impacts and develop measures

**Scale**

Integrate, automate and embed in your core business

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# Our aggregated electronics modules are adequate for screening and proxy estimates

- Electronics Database, components already highly aggregated systems (ICs, PWBs etc.)
- Still too detailed to calculate electronics or IT devices
- We offer some modules even higher aggregated – cannot be representative
- Some offered parametric to be adaptable
- Examples: populated PWBs with signal or power electronics, HDDs, connector model, cable model, TfT display, open semiconductor model

**Screen**

## When to use

- Need a proxy
- Need hotspots overview of larger systems, where electronics only one sub-aspect
- Need a fast response

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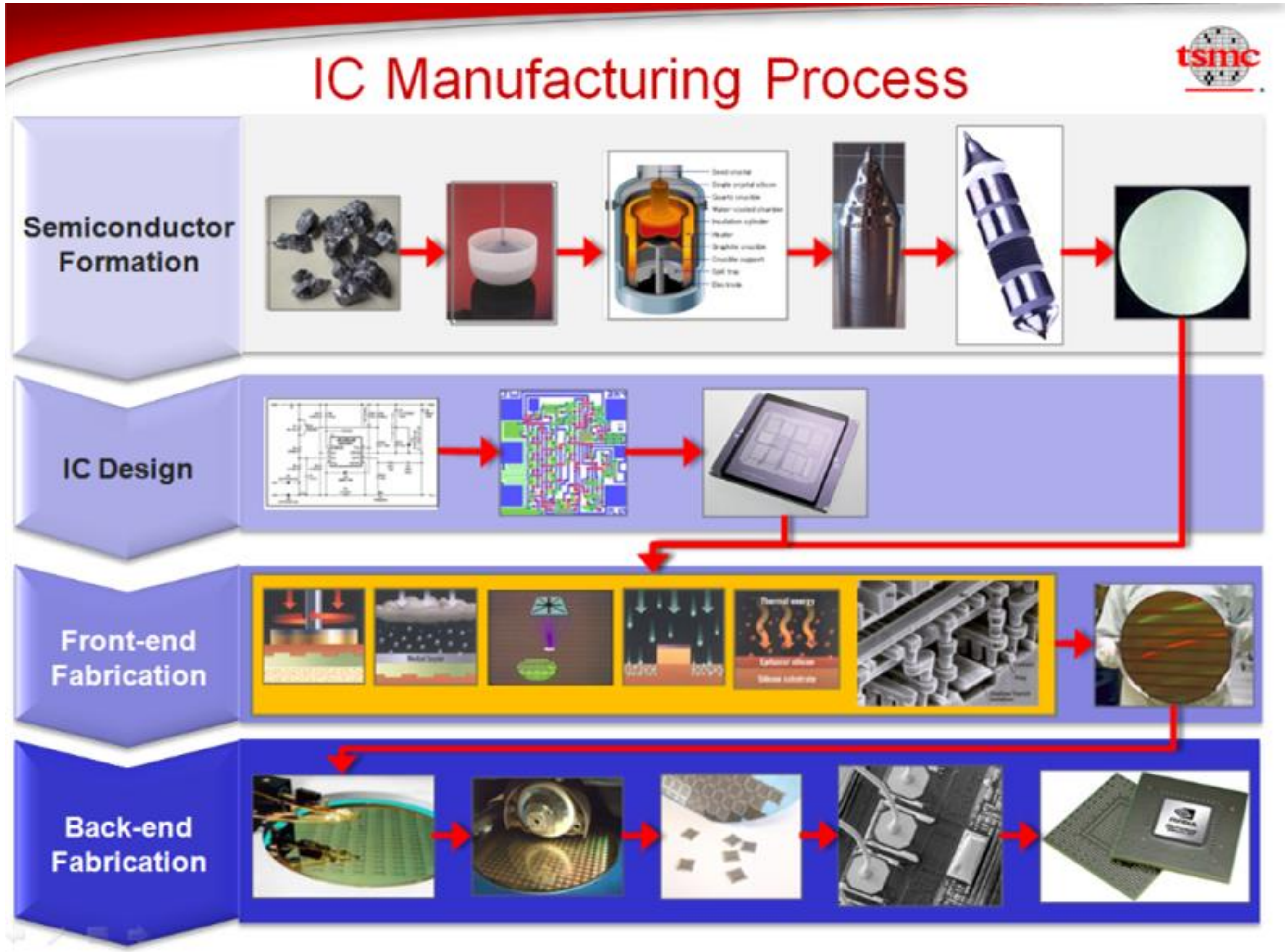
# Integrated circuits require complex manufacturing processes




Source: TSMC

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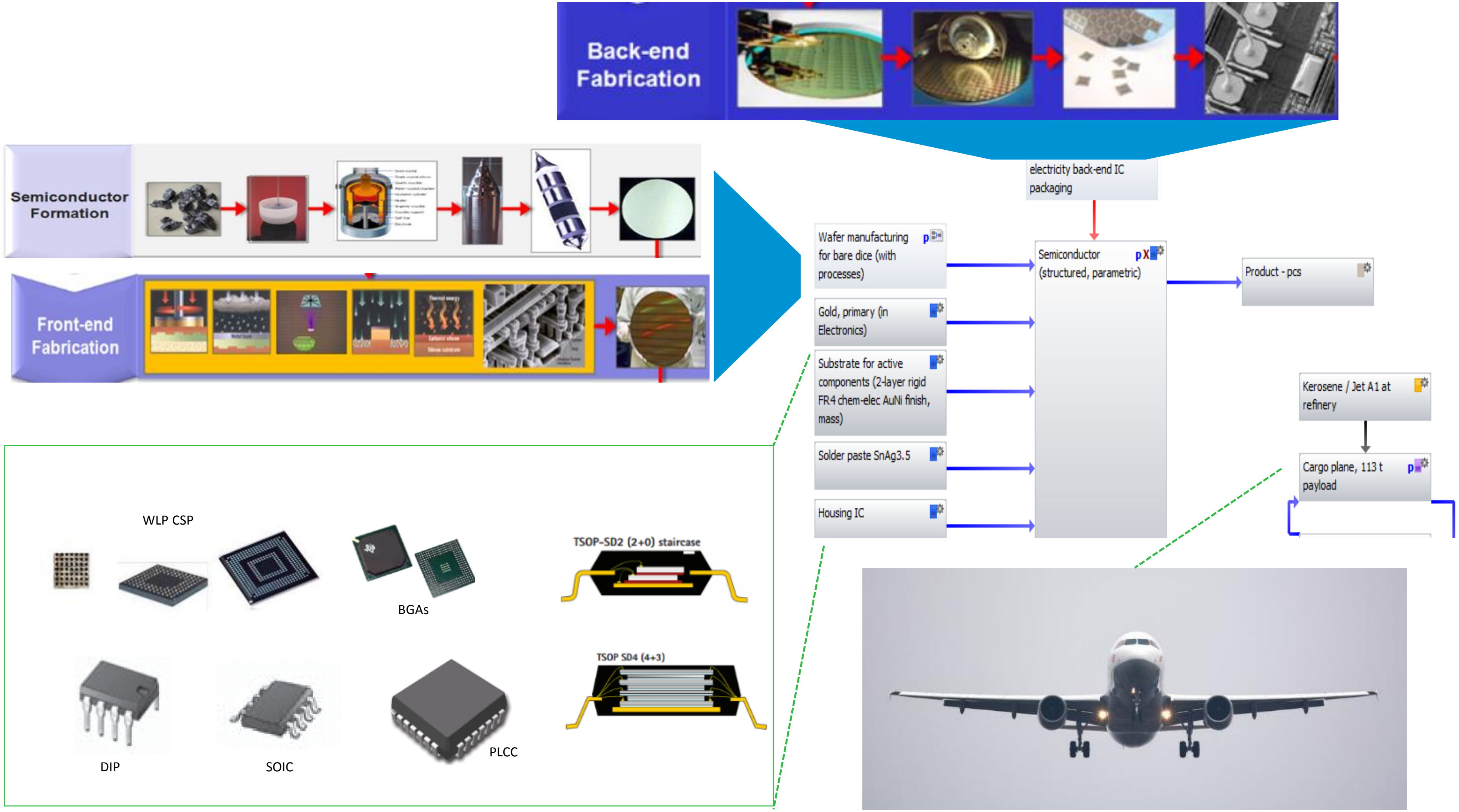
# Our underlying model is capable of assessing representative product types of semiconductor



# Our open IC model offers the flexibility to adapt parameters to increase accuracy

Open IC model – for representative product types

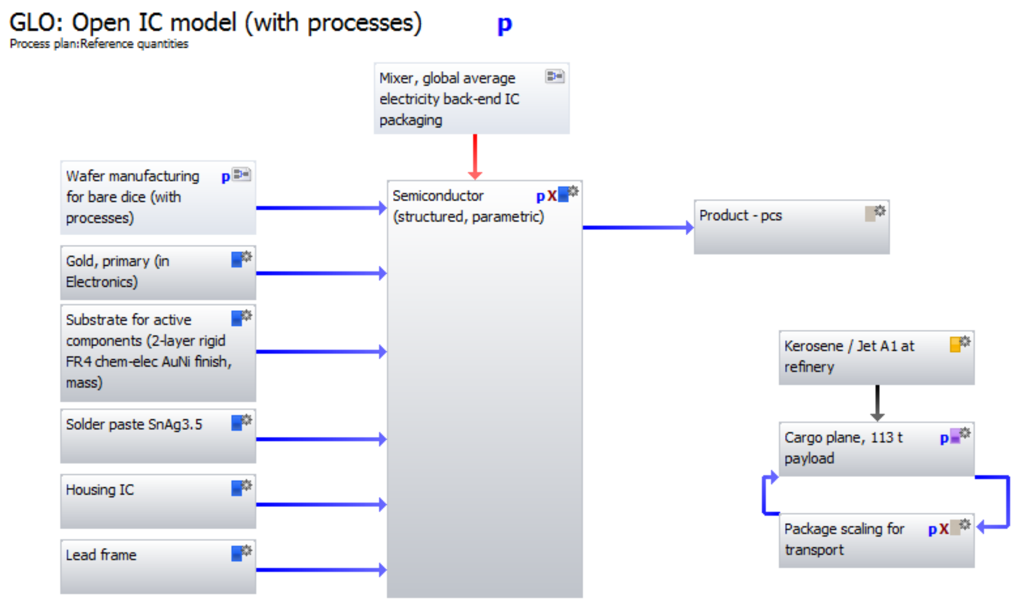
Scope

## Opening significant parameters of the semiconductor environmental profile such as

- Die size
- Techonology node (generation)
- Mass of gold, housing, leadframe

## When to use

- Specific supply chain data is still very challanging to obtain
- You want to represent your product with higher accuracy



# Representativeness risk: Same product type can have different material composition

Example of material declarations

**48- BGA (6 x 8 mm)**
**Pb-Free Package**

**B2. MATERIAL COMPOSITION (Note 3)**
**Using Copper-Palladium wire material**

| Material | Purpose of Use | Substance Composition | CAS Number | Weight by mg | % weight of substance per Homogenous | PPM | % weight of substance per package |
|---|---|---|---|---|---|---|---|
| | | | | | | | 10.2222% |
| | | | | | | | 8.0317% |
| | | | | | | | 10.9523% |
| | | | | | | | 1.8254% |
| | | | | | | | 1.8254% |
| | | | | | | | 1.8254% |
| | | | | | | | 1.8254% |
| | | | | | | | 0.3607% |
| | | | | | | | 0.0037% |
| | | | | | | | 0.0018% |
| | | | | | | | 1.3972% |
| | | | | | | | 0.1747% |
| | | | | | | | 0.1223% |
| | | | | | | | 0.0524% |
| | | | | | | | 30.5781% |
| | | | | | | | 1.4759% |
| | | | | | | | 0.0150% |
| | | | | | | | 25.3506% |
| | | | | | | | 1.4655% |
| | | | | | | | 0.7328% |
| | | | | | | | 1.6121% |
| | | | | | | | 0.1494% |
| | | | | | | | **100.0000** |

**B1. MATERIAL COMPOSITION (Note 3)**
**Using Gold wire material**

| Material | Purpose of Use | Substance | CAS Number | Weight by mg | % weight of substance per Homogenous material | PPM | % weight of substance per package |
|---|---|---|---|---|---|---|---|
| | | | | 7.2576 | 28.0000% | 100,507 | 10.0507% |
| | | | | 5.7024 | 22.0000% | 78,970 | 7.8970% |
| | | | | 7.7760 | 30.0000% | 107,686 | 10.7686% |
| | | | | 1.2960 | 5.0000% | 17,948 | 1.7948% |
| | | | | 1.2960 | 5.0000% | 17,948 | 1.7948% |
| | | | | 1.2960 | 5.0000% | 17,948 | 1.7948% |
| | | | | 1.2960 | 5.0000% | 17,948 | 1.7948% |
| | | | | 0.2561 | 98.5000% | 3,547 | 0.3547% |
| | | | | 0.0026 | 1.0000% | 36 | 0.0036% |
| | | | | 0.0013 | 0.5000% | 18 | 0.0018% |
| | | | | 0.9920 | 80.0000% | 13,738 | 1.3738% |
| | | | | 0.1240 | 10.0000% | 1,717 | 0.1717% |
| | | | | 0.0868 | 7.0000% | 1,202 | 0.1202% |
| | | | | 0.0372 | 3.0000% | 515 | 0.0515% |
| | | | | 1.7100 | 100.0000% | 300,651 | 30.0651% |
| | | | | 2.2700 | 100.0000% | 31,436 | 3.1436% |
| | | | | 8.3128 | 88.0000% | 253,603 | 25.3603% |
| | | | | 1.2486 | 6.0000% | 17,291 | 1.7291% |
| | | | | 0.4162 | 2.0000% | 5,764 | 0.5764% |
| | | | | 0.8324 | 4.0000% | 11,527 | 1.1527% |

.2100 **% Total:** **100.0000**

**48- BGA (6 x 8 mm)**
**Pb-Free Package**

**B3. MATERIAL COMPOSITION (Note 3)**
**Using Copper-Palladium wire material, & with big-die**

| Material | Purpose of Use | Substance Composition | CAS Number | Weight by mg | % weight of substance per Homogenous material | PPM | % weight of substance per package |
|---|---|---|---|---|---|---|---|
| Substrate | Base Material | Cured Resin | Trade Secret | 7.2867 | 27.9593% | 96,653 | 9.6653% |
| | | Glass Fabrics | Trade Secret | 5.8131 | 22.3051% | 77,107 | 7.7107% |
| | | Copper Foil | Trade Secret | 7.7760 | 29.8368% | 103,144 | 10.3144% |
| | | Diethylene Glycol Monoethyl Ether Acetate | Trade Secret | 1.2965 | 4.9747% | 17,197 | 1.7197% |
| | | Acetophenone Derirative | Trade Secret | 1.2965 | 4.9747% | 17,197 | 1.7197% |
| | | Silica Crystalline | Trade Secret | 1.2965 | 4.9747% | 17,197 | 1.7197% |
| | | Solvent naptha | Trade Secret | 1.2965 | 4.9747% | 17,197 | 1.7197% |
| Solder Ball | External Plating | Sn | 7440-31-5 | 0.2562 | 98.4627% | 3,398 | 0.3398% |
| | | Ag | 7440-22-4 | 0.0026 | 0.9992% | 34 | 0.0034% |
| | | Cu | 7440-50-8 | 0.0014 | 0.5380% | 19 | 0.0019% |
| Die Attach | Adhesive | Ag | 7440-22-4 | 0.9950 | 80.2419% | 13,198 | 1.3198% |
| | | Bismaleimide | Trade Secret | 0.1355 | 10.9274% | 1,797 | 0.1797% |
| | | Polymer/Synthetic Resin | Trade Secret | 0.0895 | 7.2177% | 1,187 | 0.1187% |
| | | Additive | Trade Secret | 0.0415 | 3.3468% | 550 | 0.0550% |
| Die | Circuit | Si | 7440-21-3 | 25.9500 | 100.0000% | 344,210 | 34.4210% |
| Wire | Interconnect | Cu | 7440-50-8 | 1.4579 | 99.9589% | 19,338 | 1.9338% |
| | | Pd | 5/3/7440 | 0.0006 | 0.0411% | 8 | 0.0008% |
| Mold Compound | Encapsulation | Silica Fused | 60676-86-0 | 17.5875 | 84.5143% | 233,287 | 23.3287% |
| | | Epoxy resin | Trade Secret | 1.0395 | 5.0000% | 13,788 | 1.3788% |
| | | Phenolic resin | Trade Secret | 0.5203 | 2.5000% | 6,901 | 0.6901% |
| | | Melamine Cyanurate | Trade Secret | 1.1446 | 5.5000% | 15,182 | 1.5182% |
| | | Carbon black pigment | 1333-86-4 | 0.1061 | 0.5100% | 1,407 | 0.1407% |

**Package Weight (mg):** **75.3900** **% Total:** **100.0000**

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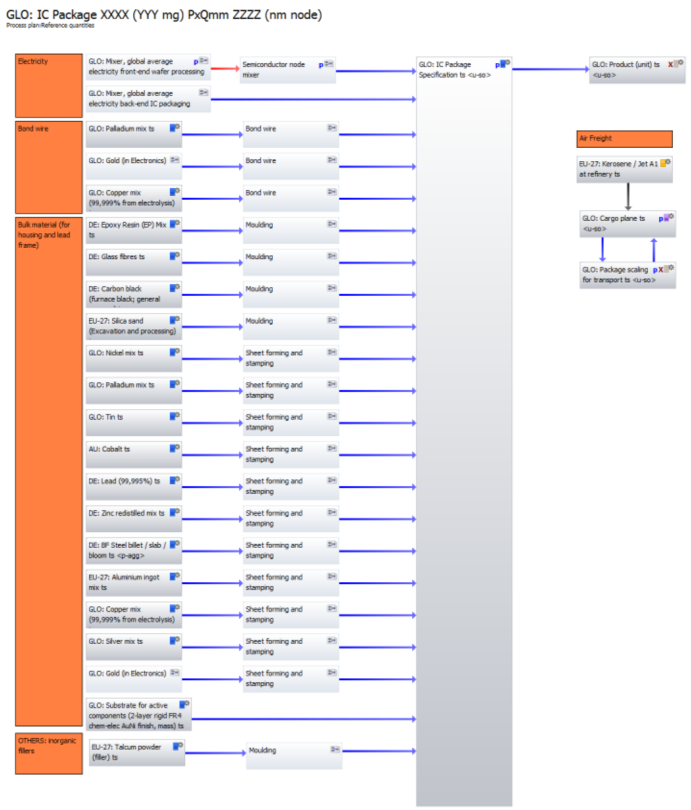
# Our material declaration-based model evaluates a specific product in a specific supply chain

Scale

## Material Declaration based model (from representative to specific product modeling)

Opening significant parameters and full flexibiliy to model a specific product type

- Electricity grid mix (front-end and back-end)
- Die size
- Bond wire
- All material masses
- Technology node (generation)
- Transportation from manufacturing to assembly




Advantages

- Best available info / most accurate results
- Unlimited reproducibility of other ICs
- Ability to see the material declaration values of all existing GaBi database ICs (parameter explorer)

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# Summary and Lessons Learned

# The New Normal

- Zero carbon target is main driver for LCT
- Scope 3 calculation typically involves electronics as it is part of our live, business and products
- Electronics and data management (internet, cloud etc.) are part of all sectors and all sectors analyse their footprints
- Electronics, product service systems (PSS), smartness, digitalization and virtualization improve systems (better handprint compared to state of the art), but electronics have a significant environmental footprint
  - Complex systems
  - Impact independent from mass
  - In-transparent supply chains
  - Up to 90% are elements are employed from periodic table of elements

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# Drivers of Environmental Impact Contribution in Electronic Products

## 4 aspects rule – order can switch depending on type of product

| | |
|---|---|
| Rule #1: **Size of PWB** | Substrates may be single or multiple layered. Each layer means more processing steps, more energy and materials |
| | Substrates may have Gold-Nickel finishing, see rule #4 |
| Rule #2: **Number and type of ICs** | The die size largely determines the impact of the IC, because of the highly energy-intensive operations upstream (wafer fab) |
| | ICs contain gold, silver and other precious metals, see rule #4 |
| | Large ICs, such as the Northbridge and Southbridge of computer motherboards, also contain a substrate of their own (multi chip modules, MCM) |
| Rule #3: **Mass** | Higher mass, higher energy input, if the other rules are exhausted |
| | 20 g can be heavy on a board of 10 g, e.g. large capacitor or ring core coil vs. a tiny simple IC |
| | Heavy chassis, housing or frames around electronics |
| Rule #4: **Anything that is precious** | Precious metals have the highest impacts per mass (commodities) |
| | Gold and gold plating, e.g. PWBs, connectors, pins, contacts, bond wires etc. |
| | The smaller the electronics (miniaturization) the more purity and precious metals are used per total mass of electronics |

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# Questions?

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