Key IC data for an accurate life cycle assessment of ICT devices

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Fraunhofer IZM

Technology Development

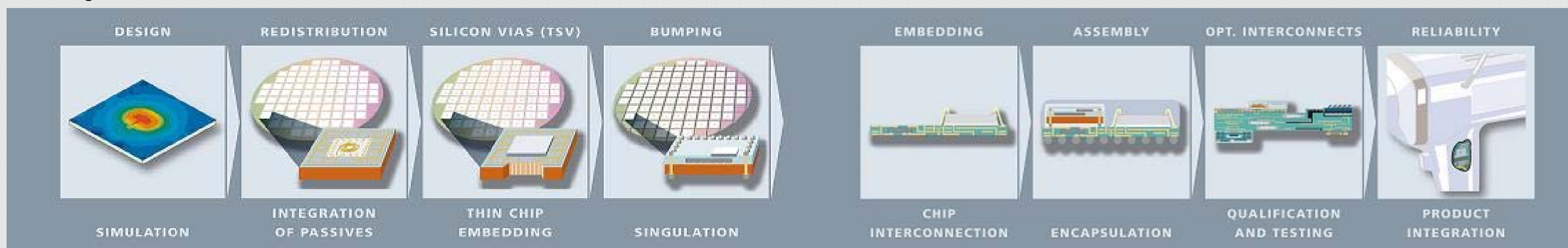
From Lab to Fab

Material and Technology Developmen t

Module design, hetero-system integration

System design, manufacturing & testing

Smart system, function / product integration

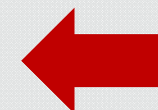


Wafer-Level & Panel-Level Packaging

Embedding of active & passive components

Reliability assessment and Testing

Sustainability assessment and Ecodesign

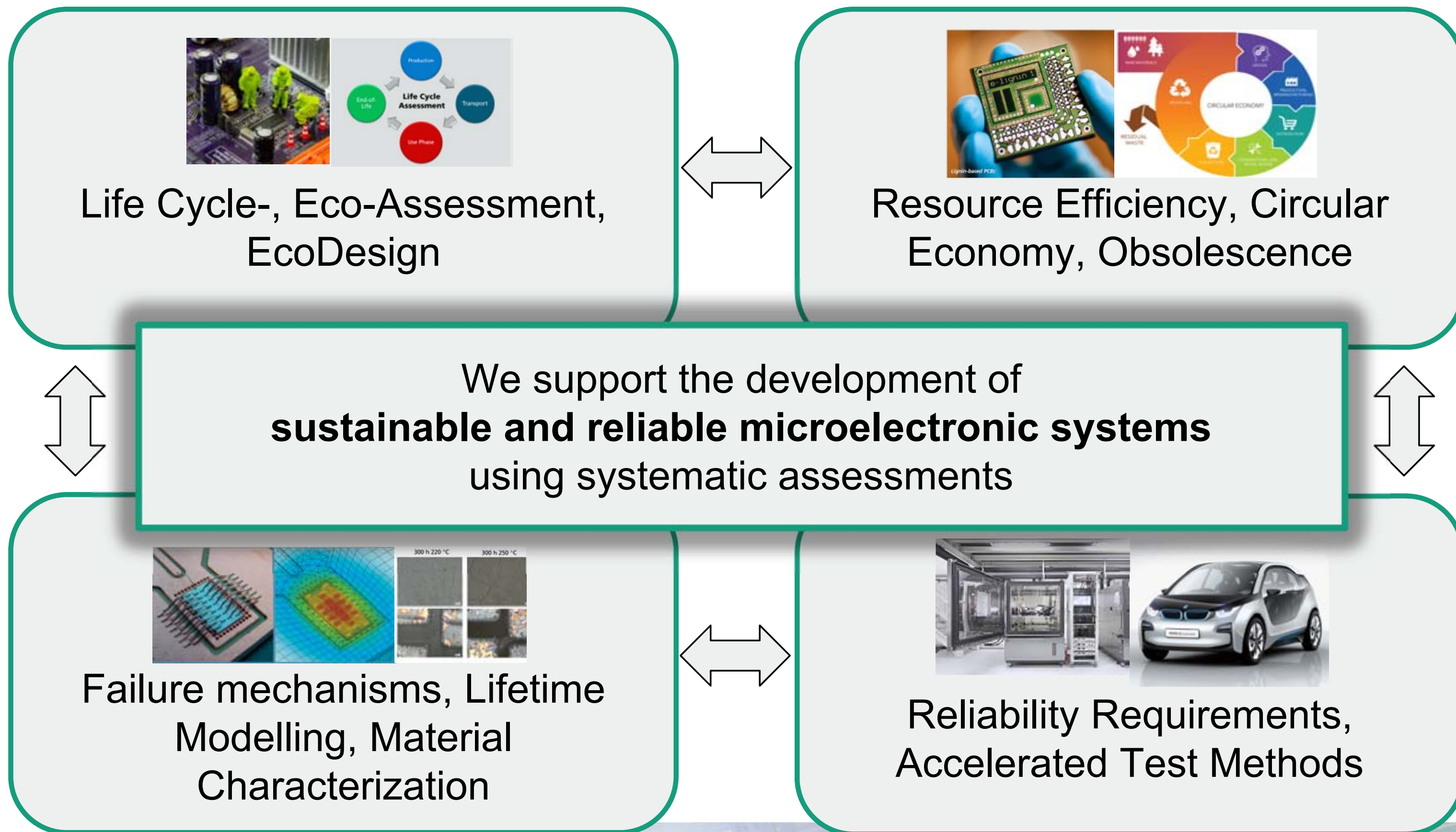


Module & System Design

Assessment & Testing

Dept. Environmental and Reliability Engineering ERE

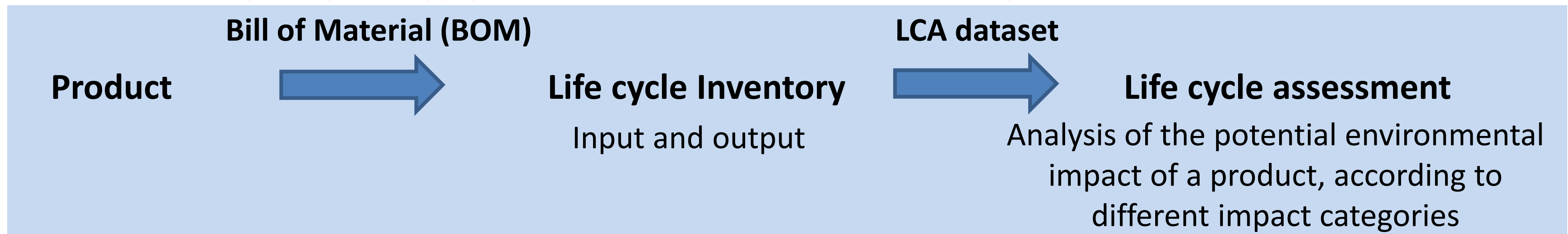
Our Mission



Main phases of an LCA

Specificity of ICT

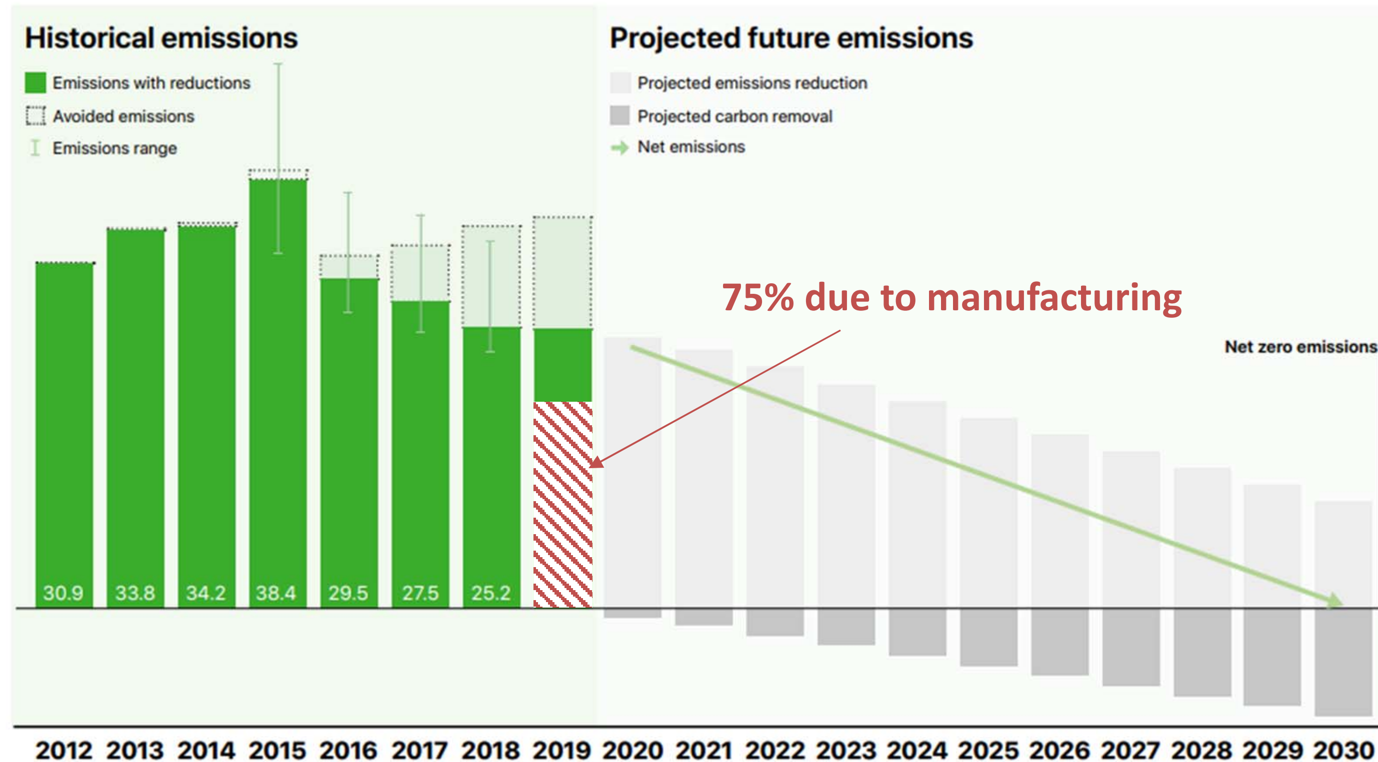
ICT devices: Very complex supply chain Datasets are currently insufficient



For ICT devices: Manufacturing phase usually causes the highest environmental impact (short lifetime, low power consumption)

Net Zero Targets: driver towards low-emission manufacturing process and high-quality LCA data

Apple historical and projected emissions (Scope 1,2,3) from 2012 to 2030



Compensation = money !

Source: Apple environmental progress report 2020

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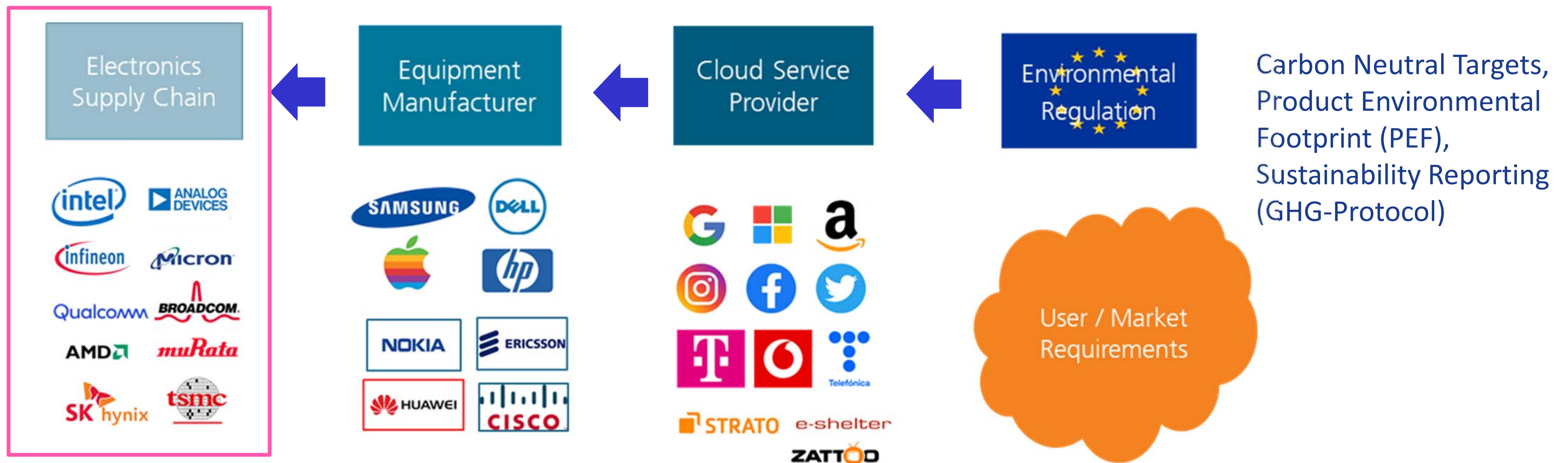
Net Zero Targets: driver towards low-emission manufacturing process and high-quality LCA data

The production of the core PCB causes the highest impact: 71%

Source: Life cycle assessment of Fairphone 3 (Fraunhofer IZM)

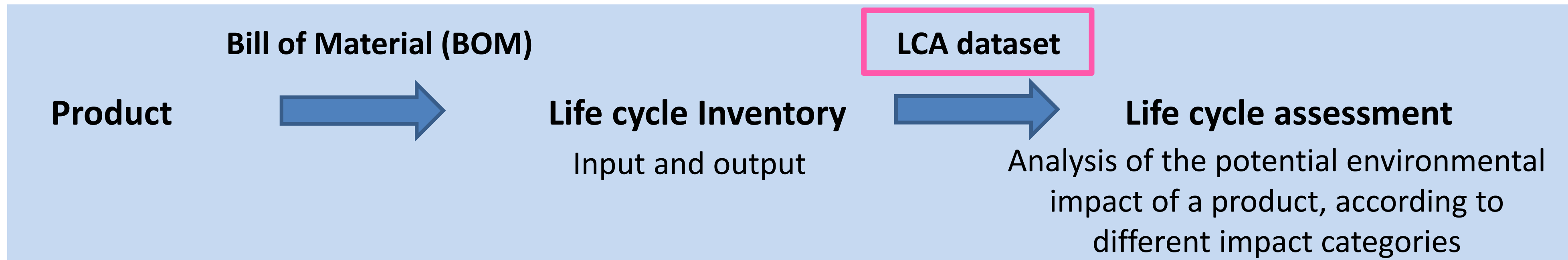
Equipment & component manufacturers must provide accurate data



Pressure on the electronics supply chain

Main phases of an LCA

What kind of data are needed for an LCA?



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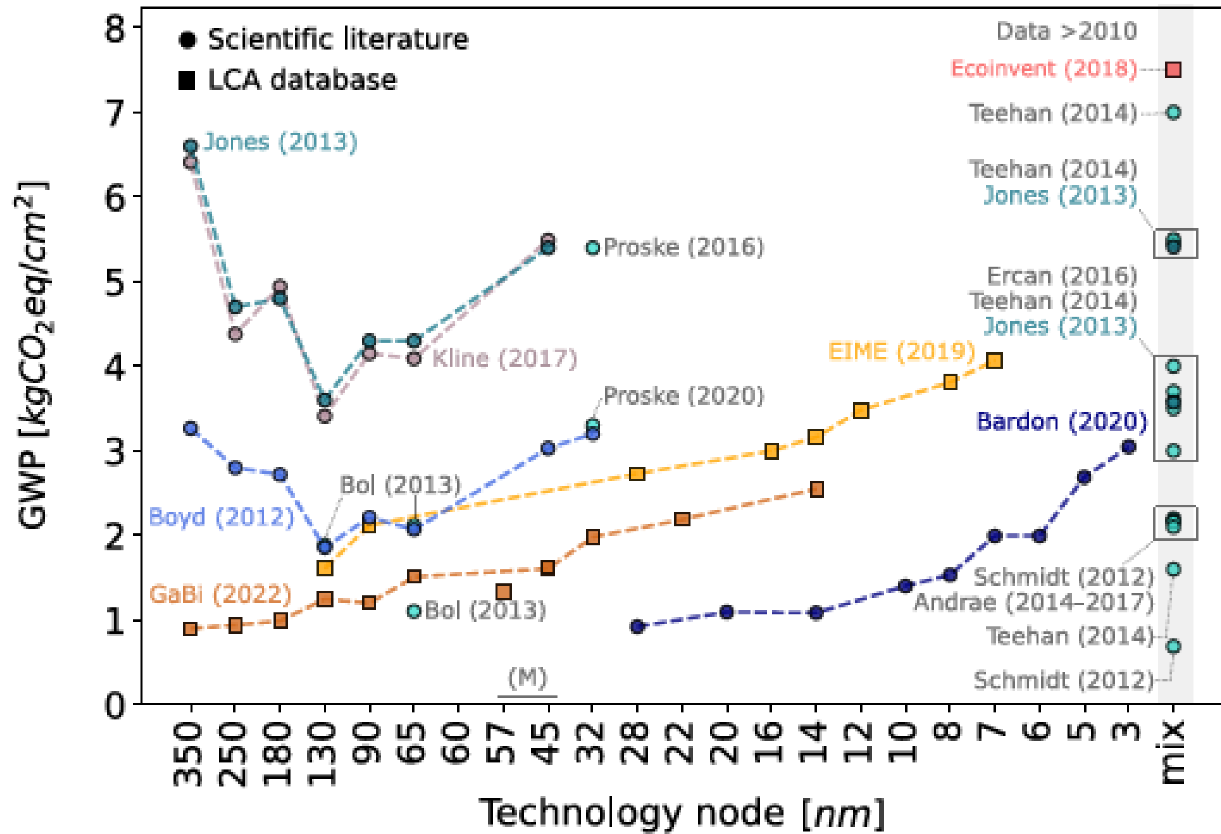
Actual LCA dataset

Comparison of GWP per die area between the data sets



Source: Pirson et al. (2022) “The Environmental Footprint of IC Production: Review, Analysis and Lessons from Historical Trends”

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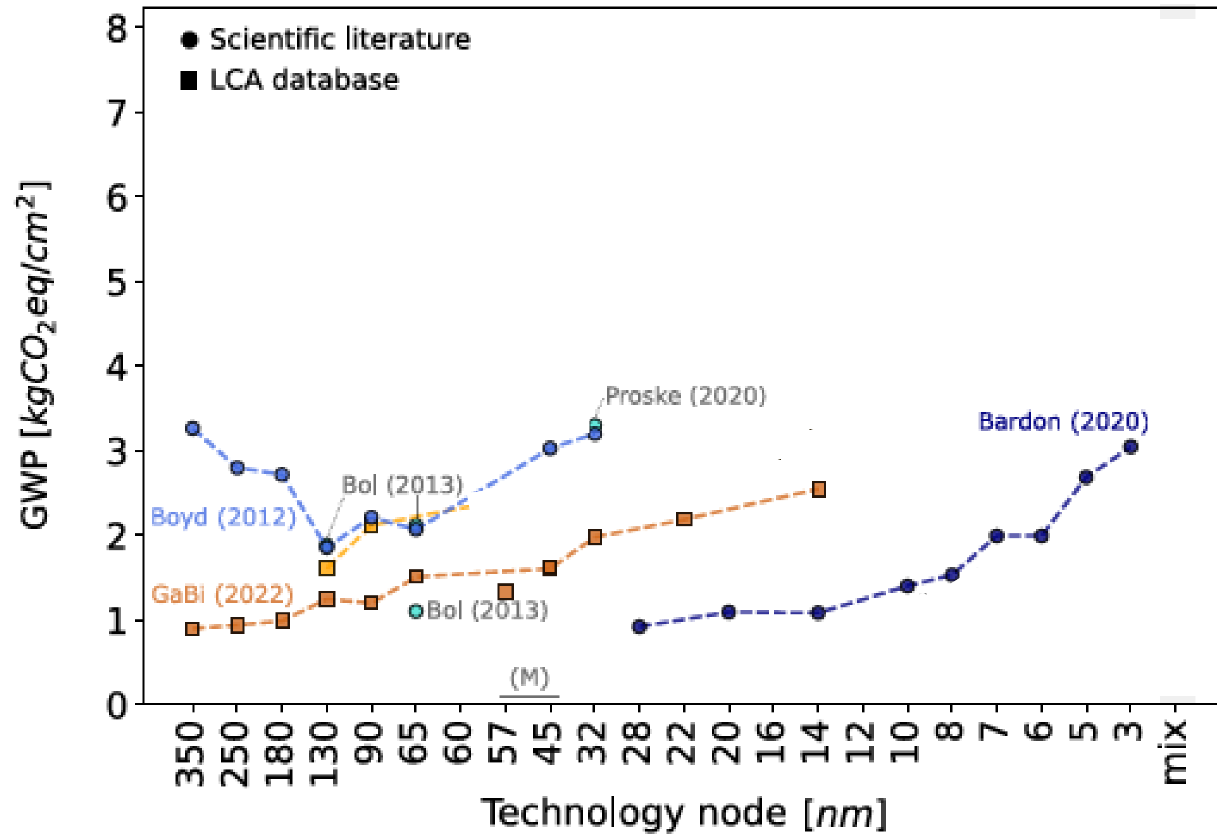
Actual LCA dataset

Large discrepancy between the data sets



Source: Pirson et al. (2022) “The Environmental Footprint of IC Production: Review, Analysis and Lessons from Historical Trends”

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Evaluation of parameters recorded in the IC data sets

	Boyd (2012)	Bardon et al. (2020)	GaBi LCA database (2022)
Energy demand of raw wafer production	✓ (2002)	✗	✓ (unknown)
Process energy FEOL & BEOL	✓	✓	✓
Process Energy Packaging & (Testing)	✗	✗	✓
Production yield	✓	✗	✓
Direct emissions of chemicals & gases	✓	✓	✓
Energy for the operation of the clean room & sub-fab infrastructure (proportionate)	✓ (Part of process energy)	✓ (percentage surcharge)	✓ (unclear)
Chemical Manufacturing (proportionate)	✓ (tw. 1997)	✗	✓
Machine manufacturing (proportionate)	✓ (1997)	✗	?
Infrastructure production (proportionate)	✓ (1997)	✗	?
	Detailled but old	**New, but uncomplete**	**Intransparent**

Source: Pirson et al. (2022) “The Environmental Footprint of IC Production: Review, Analysis and Lessons from Historical Trends”

Main phases of an LCA

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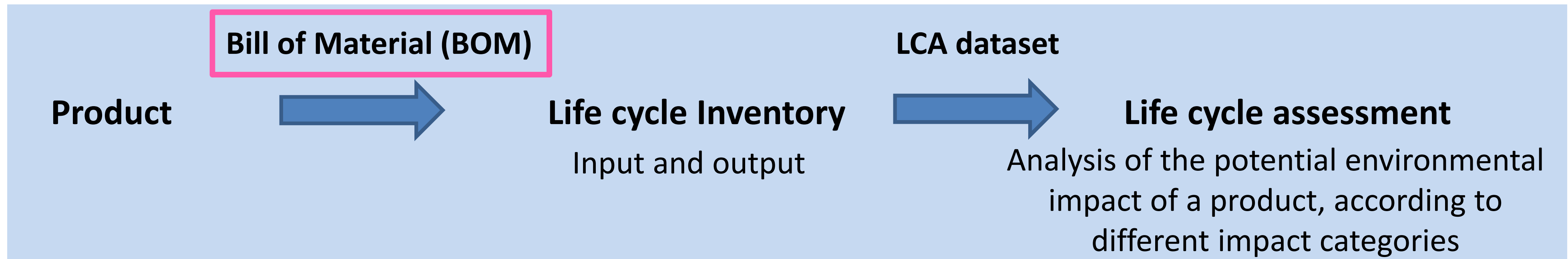
Specificity of ICT



LCA of a populated PCB

Example of BOM for a populated PCB

IC,SDRAM,1GBIT,64MX16BIT,1.35V,DDR3L-1600,11-11-11,SM,FBGA-96,NT5CC64M16GP-DII,INDUSTRIAL
IC,SW,WLAN,802.11A/B/G/N/AC,1.9-5V,INSERTION LOSS=0.5DB,H ISOLATION=30DB,SM,DFN-8-64,NJG1804K64
IC,MPU,VIDEO,1.1V,380MW,1080P@30FPS,SM,BGA-256,OV00798-B56G-1C
IC,SENSOR,IMAGE,1080P,2688X1520P,4MP,10BIT RAW,1.1-3.0V,SM,CSP5-67,OV04686-H67A
IC,WLAN/BT,802.11A/B/G/N,BT 5,802.15.4,SM,QCA-4020-1-217MSP,I-TEMP
IC,SW,RF,SPDT,5V,0.03-6GHZ,33DBM,SM,QFN-6,RTC6608OSP
IC,SW,DPDT,DUAL BAND,4.5V,2.4-2.5GHZ,4.9-6GHZ,PIN=30DBM,SM,QFN-6,RTC6615H
IC,REG,LDO,LINEAR,2.5-5.5V,350MA,VOUT=3.3V,SM,SOT-23-5,G2259-330T11U
IC,CNVT,2.5-6V,1.2A,2000KHZ,SM,WSON-8,TLV62080DSG
IC,MCU,24MHZ,16BIT RISC,32KB FRAM,4KB SRAM,12BIT ADC,1.8-3.6V,SM,LQFP-48,MSP430FR2155TPTR

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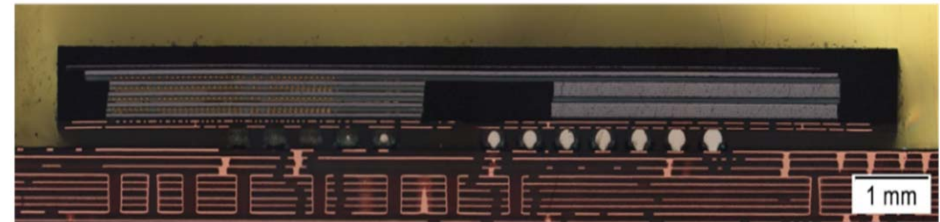
Accurate assessment of semiconductor die in package

Destructive analysis to assess the number of dies and total semiconductor area in package



Memory chip

Source: Billaud et al. CARE INNOVATION conference paper "ICs as drivers of ICT carbon footprint: an approach to more accurate die size assessment"

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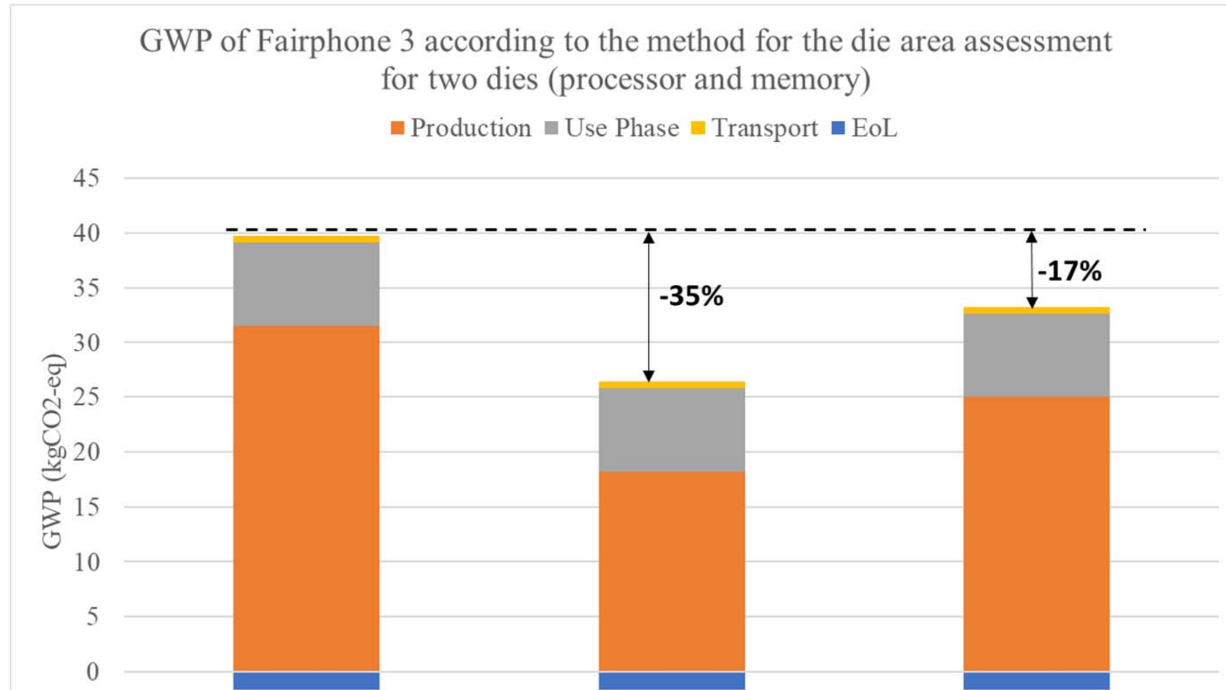
Accurate assessment of semiconductor die in package



chip	Destructive analysis	Assumption 1 DPR* = 8%	Assumption 2 DPR* = 80%
Memory chip	**508 mm²**	12 mm²	120 mm²
SoC	**47 mm²**	13 mm³	134 mm²

Variation in semiconductor content has a high impact on the LCA results

This assumption is usually not mentioned in LCA !!

*DPR= die-to-package ratio

Source: Billaud et al. CARE INNOVATION conference paper "ICs as drivers of ICT carbon footprint: an approach to more accurate die size assessment"

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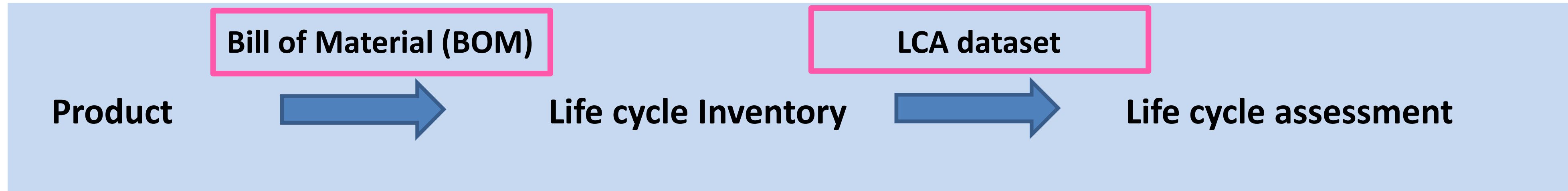
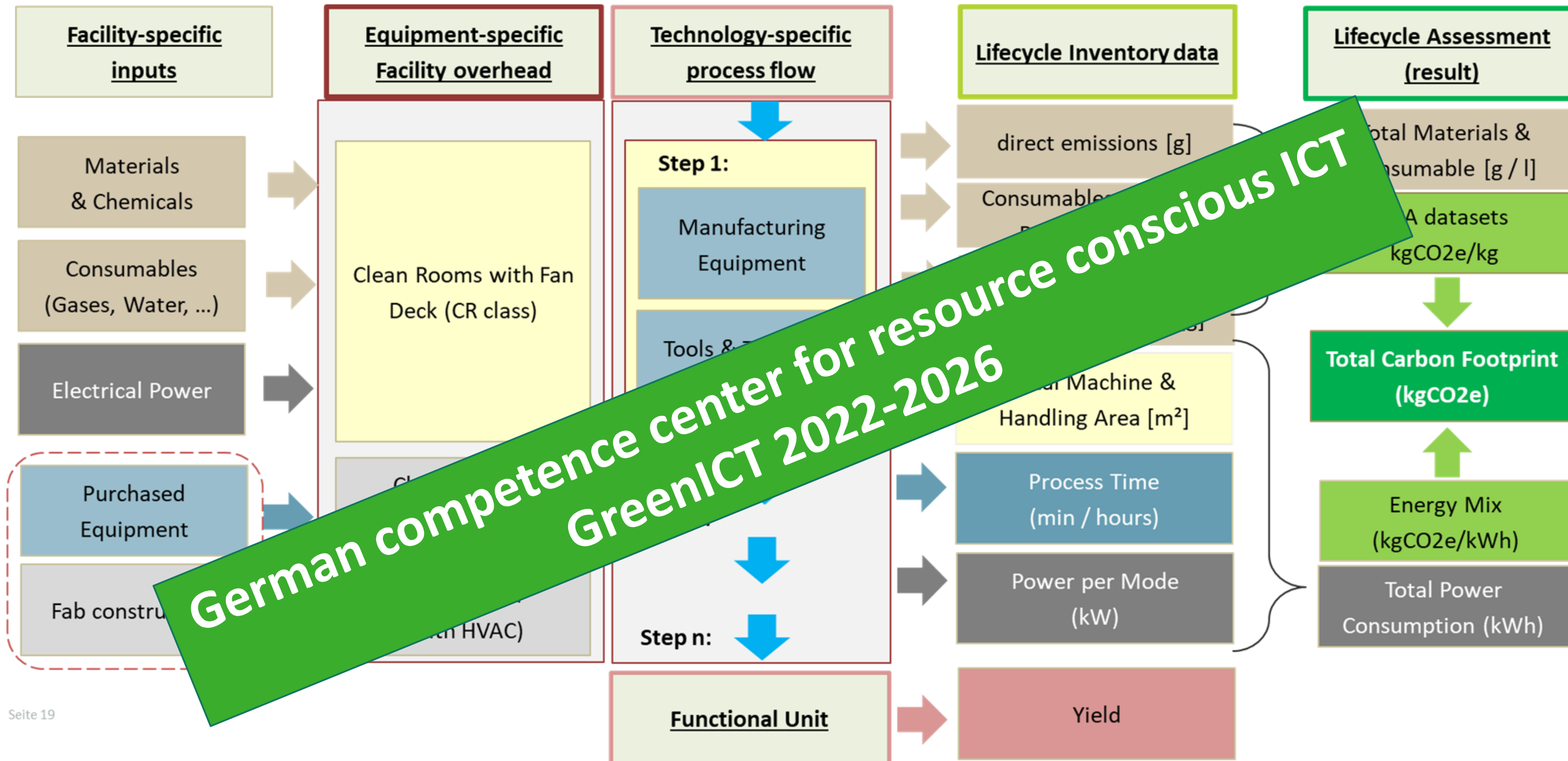
Wish list for an accurate LCA of ICT



- Key IC data from a product
  - Number and size of dies in package
  - Type of semiconductor
  - Type of package
  - Technology node or memory technology
- Key IC data in LCA dataset
  - Transparent methodology
  - At least two impact categories ADP and GWP
  - Impact per chip type, technology node, and package type

Not exhaustive!

Data requirements for life cycle assessment of IC production (process step-specific) Equipment-specific carbon footprint and overall process



https://greenict.de/ueber-fmd/

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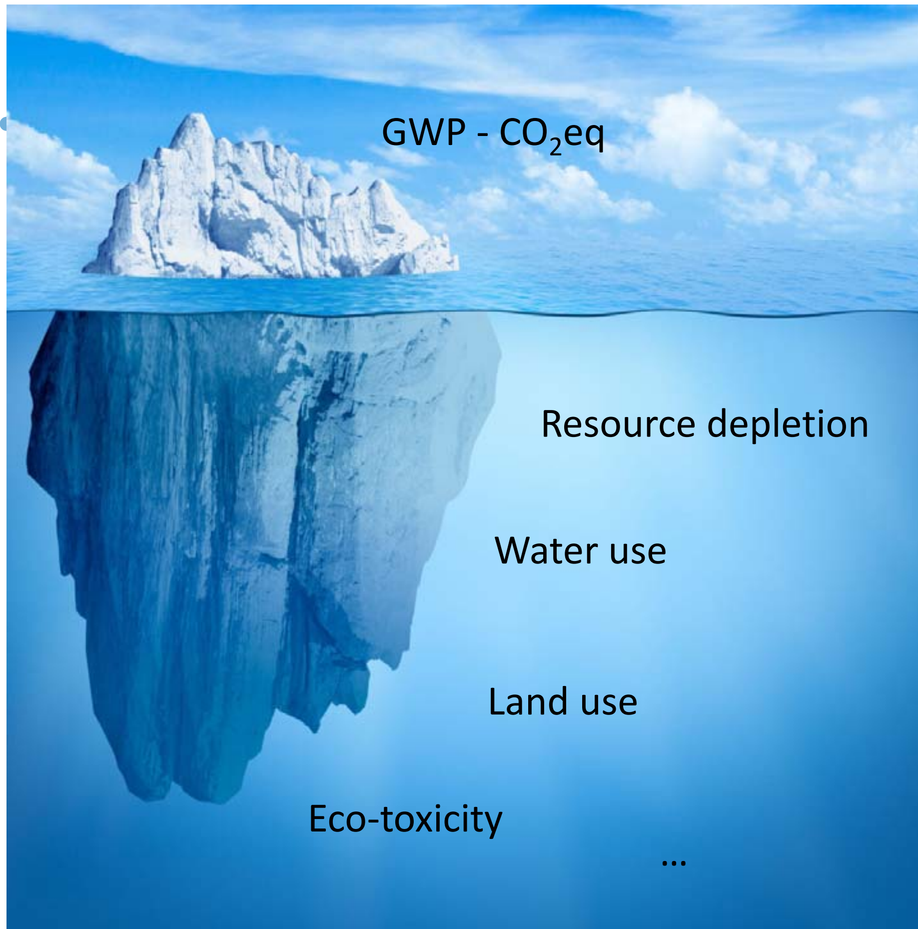

For gold, silver and palladium in IC packages for the core module of Fairphone 3

3 mg of Au, Ag, Pd ➡ ~ 4 kg of rock extracted

For WW smartphone production in 2021

More than 5 million tonnes rock extracted

Source: USGS 2022 "Rock-to-Metal Ratio: A Foundational Metric for Understanding Mine Wastes"
Source: LCA of Fairphone 3

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