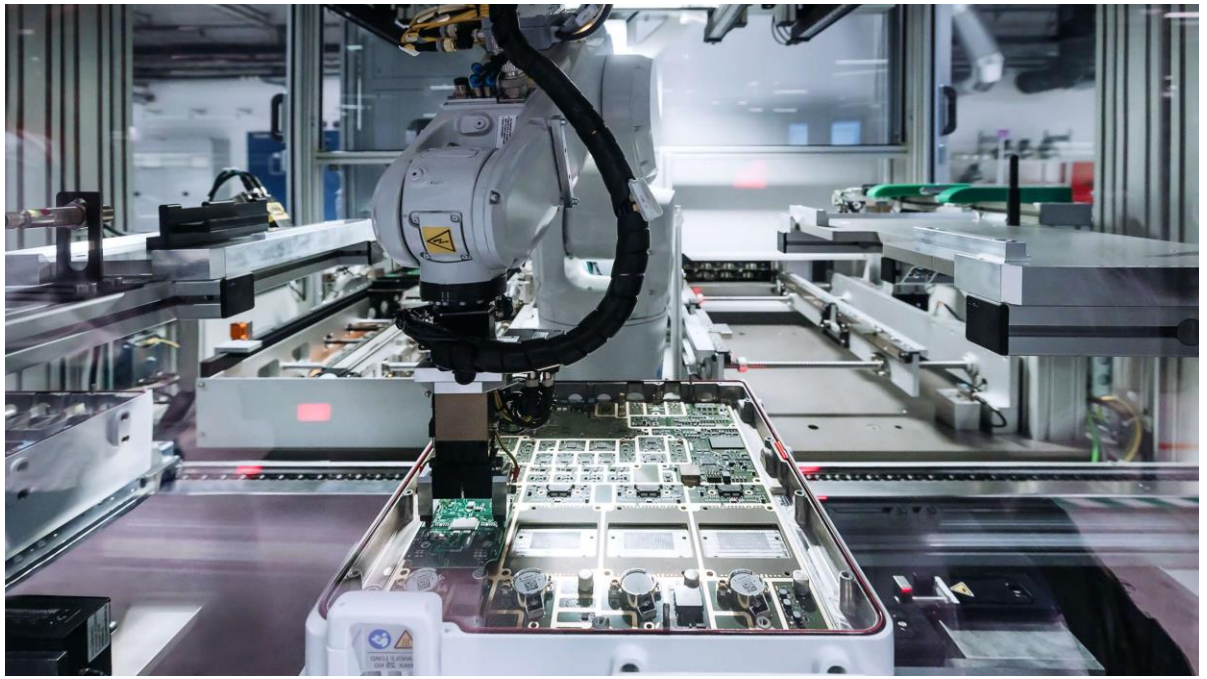
Simplified life cycle assessment methodology

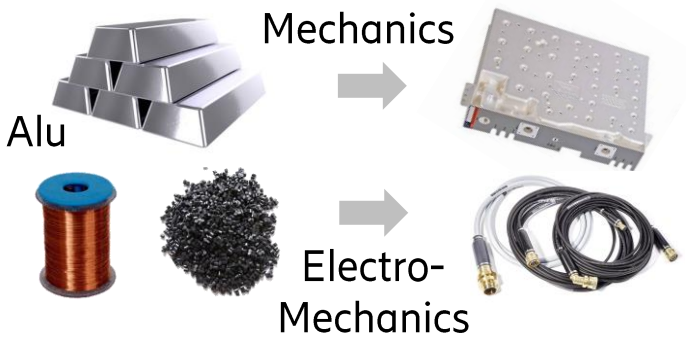


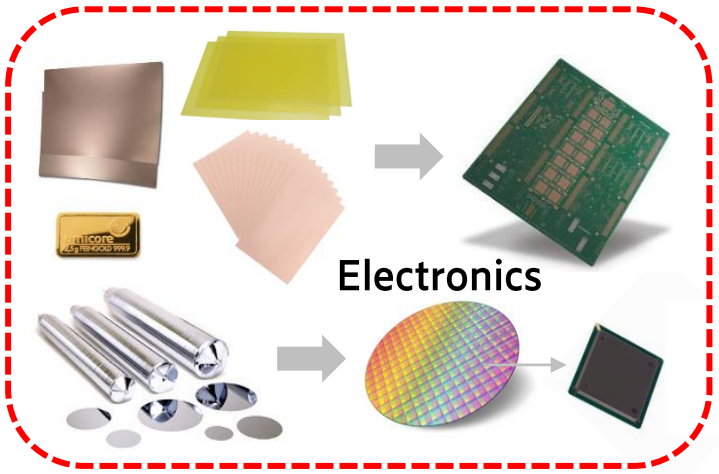
ITU-ETSI Symposium on ICT Sustainability:
Standards Driving Environmental Innovation
11 December 2024

Nina Lövehagen
Ericsson Research

Life Cycle Assessment (LCA)

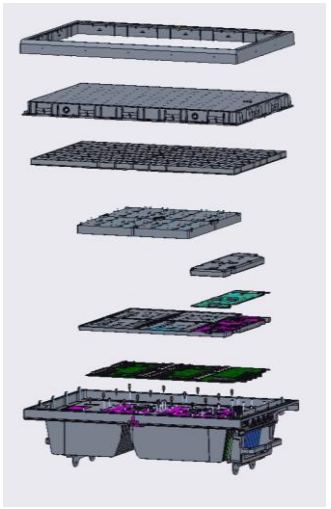
Raw material aqusition | Production | Use (X years) | End of life treatment (EoLT)





Ericsson:
R&D (Design/SW)
Market & Sales
(offices/travel)

Final assembly
Transports



"Radio"

Metal recycling

Future scenario

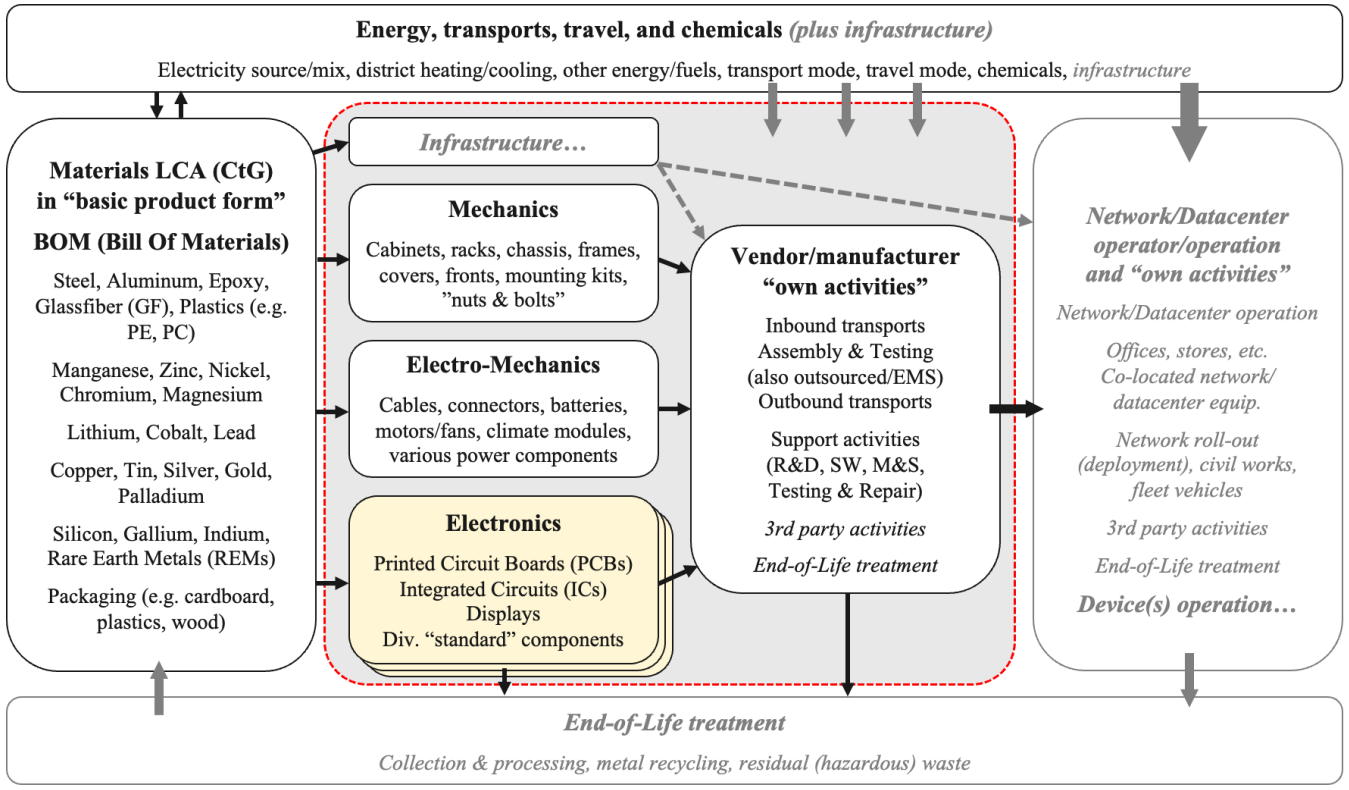
LCA of an EEE product

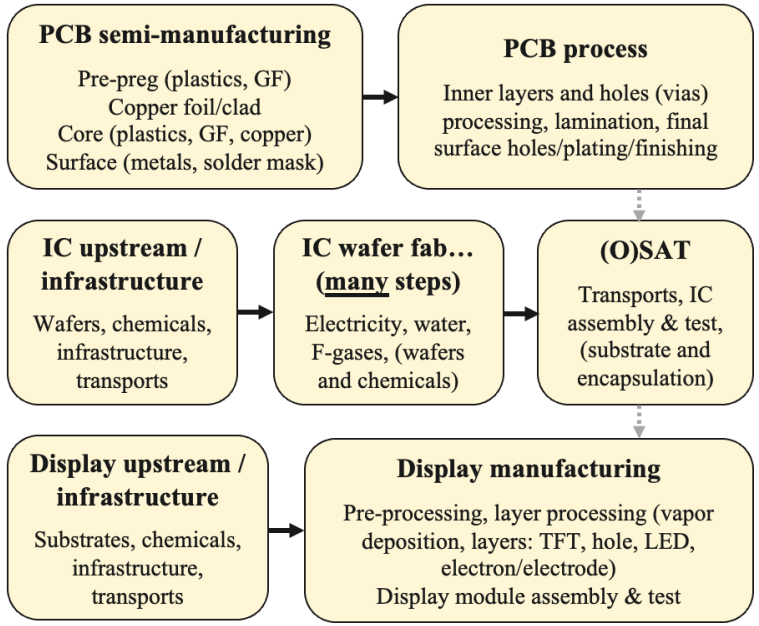
2G–4G RAN Radio

global supply chain,
>>1000 components,
>100 suppliers

2 x 80 W, 18–19 kg, (150 W average)
17 kg aluminum (Al)
0.75 kg plastics/glassfiber
0.6 kg steel (Fe), 0.35 kg copper (Cu)
25 g tin/silver/gold (Sn/Ag/Au)

540 g PCB (9.3 dm^2), 5.5–8 cm^2 IC die area





Simplified LCA methodology

Embodied emissions

- Product parameters, PP
- Factor, f
- Emission factors, EF

Cover life cycle stages: raw material acquisition, production and End-of-life treatment (EoLT)

Use stage emissions

- Annual electricity consumption, AEC
- Active lifetime years, ALY
- Electricity emission factor, EEF

Total lifetime emissions = embodied emissions + use stage emissions

Simplified LCA methodology

Embodied emissions

- Product parameters, PP
- Factor, f
- Emission factors (EF)

Simplified embodied LCA estimate
(requires an existing LCA study to create the EF)

Simplified LCA: Product Parameter Method
(no existing LCA study required, use of existing EFs)

Use stage emissions

- Annual electricity consumption, AEC
- Active lifetime years, ALY
- Electricity emission factor, EEF

$$\mathrm{AEC} \times ALY \times EEF$$

Average AEC and ALY for all products over their lifetime
(not counting inactive life years before EoLT)
"The use stage for products that operates using only electricity is typically so simple the equation above covers the basic needs."

Total lifetime emissions = embodied emissions + use stage emissions

Embodied emissions in simplified LCA methodology

Simplified embodied LCA estimate

(requires an existing LCA study to create the EF)

$$\mathbf{PP \times f \times EF}$$

PP = weight, volume, size, cost (most common)
f = 1 in most cases
PP (special cases) = % of use or based on cost

If n >1 but <10 PPs is used, it is still to be considered an embodied LCA estimate where each estimate are just added together

Simplified LCA: Product Parameter Method

(no existing LCA study required, use existing EFs)

$$\sum_{n} (PPn \times fn \times EFn)$$

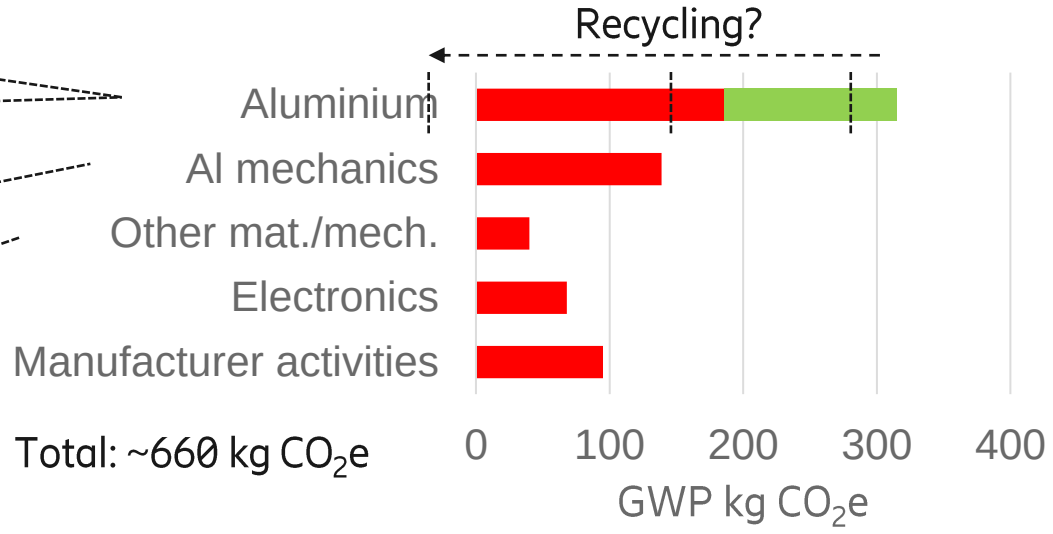
PP = Materials, Processes, Transports, Assembly & Test and end of life treatment (EoLT)

n >= 10 (an exact number cannot be stated)

Product parameter method applied on Radio

	PP	$\times F$	$\times EF$
Aluminium (S1)	16.7 kg * 1.25 * **15.1** = 315 kg		
Aluminium (S2)	16.7 kg * 1.25 * **8.9** = 186 kg		
Al die cast to finish	11.1 kg * **7.5** = 83 kg		
Al die cast + complex filter	5.6 kg * **10** = 56 kg		
Other material/mechanics	~40 kg		
Average IC (dies)	7.9 cm^2 * **2.6** = 21 kg		
Multilayer (8-12) PCB	9.3 dm^2 * 1.2 * **3** = 33 kg		
Standard components (include. IC encapsulations)	0.44 kg * **32** = 14 kg		
Transports in/out	21.2 kg * **2.5** = 53 kg		
Sites & employees	21.2 kg * **1.25** = 27 kg		
Assembly & test (+EMS)	21.2 kg * **0.74** = 16 kg		

Embodied



Total: ~660 kg CO_2e

Use stage

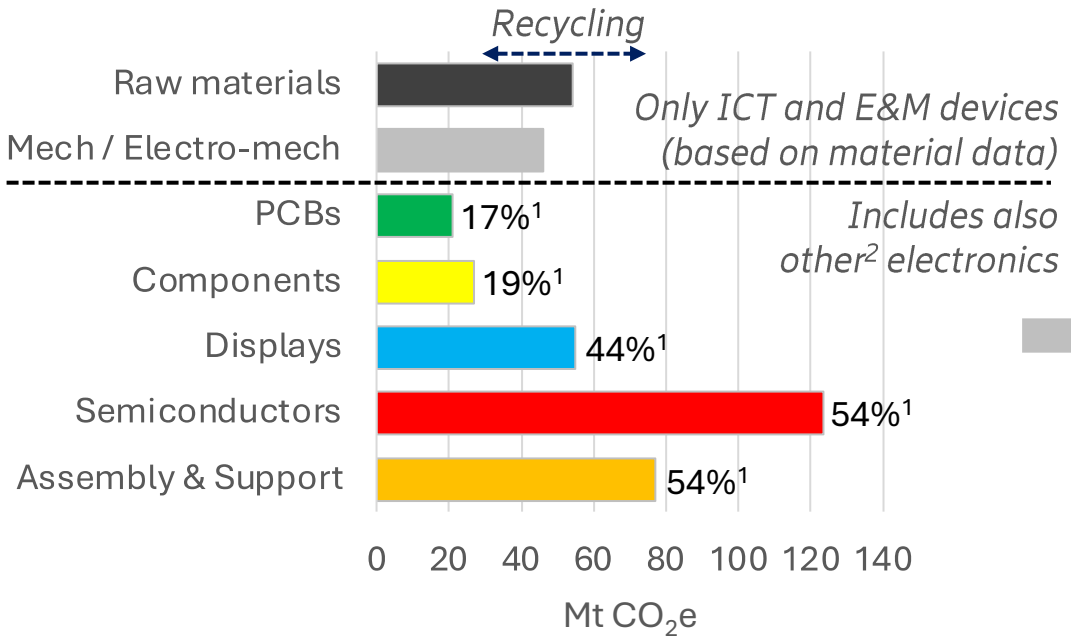
150 W x 8 years is about 10500 kWh

10500 kWh x 0.53 kg CO_2e/kWh = ~5600 kg CO_2e

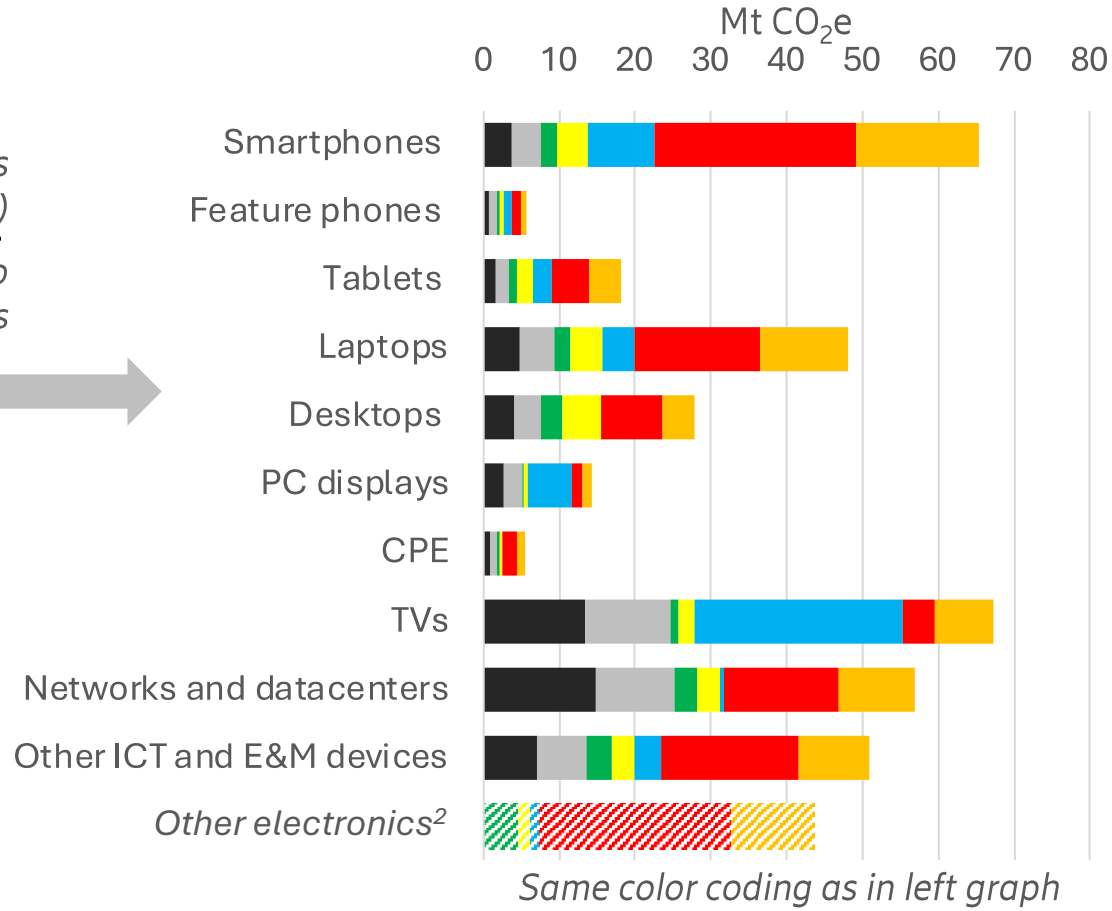
Total lifetime GWP ~6200 kg CO_2e

Emission factors can be created for any impact category following the same steps

Embodied Carbon Footprint of (ICT) Electronics



The supply chain approach
Electronics production carbon footprint 2020



Same color coding as in left graph

[1] Measured / reported data from about 60 companies covering about 36% of total estimated carbon footprint (More companies have been used as references)

Other ICT and E&M devices: Fixed phones, STBs, Audio devices, Public and commercial displays, Smart meters, Smart home devices, Payment terminals, Surveillance cameras, Others

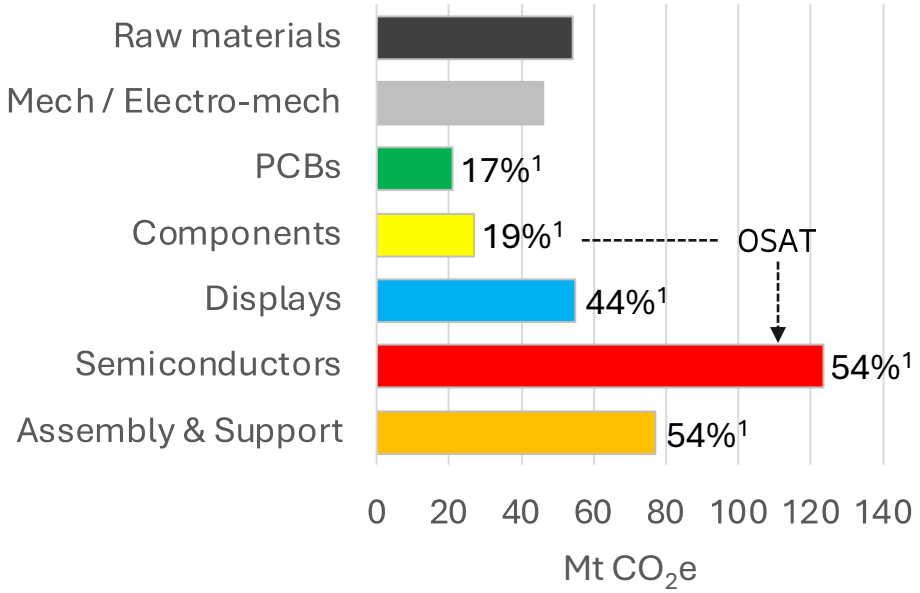
Other electronics: Appliances / tools, Automotive / aviation, Medical (health care), Industry (production), Government / military

[2] Not 100% of other electronics (but likely major part). It is the share that "got" included in the ICT and E&M manufacturers total data (as components and assembly/support are for all electronics).

E&M = Entertainment & Media sector
MT = million metric ton

Source: Lövehagen et al. 2023 https://www.sciencedirect.com/science/article/pii/S1364032123002794

Supply chain approach for semiconductors (ICs)



The <u>supply chain approach</u>
Electronics production carbon footprint <u>2020</u>

[1] Measured / reported data from about 60 companies covering about 36% of total estimated carbon footprint (More companies have been used as references)

Year 2020

TSMC	16.1 TWh
Samsung IC	13.6 TWh
SK Hynix	9.7 TWh
Intel	8.8 TWh
Micron	6.8 TWh
GlobalFoundries	3.0 TWh
UMC	2.6 TWh
Texas instruments	2.5 TWh
ST	2.4 TWh
Infineon	2.0 TWh
SMIC	1.6 TWh
NXP	1.5 TWh
Qualcomm, Nvidia, Broadcom, AMD	1.2 TWh

Total: **72 TWh**
(13.7 TWh renewables)
Scope 2: **29 Mt CO_2e** (market)

Scope 1: 19 Mt CO_2e

Scope 3: 17 Mt CO_2e (uncertain)

Total reported: **66 Mt CO_2e**

Extrapolations, estimates, and LCA as a "gap filler":
+55 Mt CO_2e (uncertain)

Final total: **121 Mt CO_2e**

+OSAT: +7 = **128 Mt CO_2e**

OSAT = Outsourced Semiconductor Assembly & Test
MT = million metric ton

Source: Lövehagen et al. 2023 https://www.sciencedirect.com/science/article/pii/S1364032123002794

Key components

	Raw Materials	Processing (scope) Energy, process materials, infrastructure, "overhead"			
ICs	Wafer, process, encapsulation ...materials	Wafers	→ Wafer fab →	**IC** (O)SAT	Low-end: 1.5 kg Memories: 2.2 kg **Average: 2.6 kg CO_2e / cm^2 die area** Special types: 4 kg High-end: 5 kg Tech front: 10+ kg
PCBs	Copper, Epoxy, Glass fiber (GF), Silver/Gold	Prepreg, copper foil, CCL, others	→ PCB processing		Basic rigid/flex (1-2 layers): 1 kg Average multilayer (<8 layers): 2.5 kg **Average (8-12): 3 kg CO_2e / dm^2 PCB area** Average multilayer (>12 layers): 3.5 kg HDI / IC substrate: 9 kg
Displays	Substrate, film, layer, electrode ...materials	Substrate/layer processing	→ Display assembly & test		TV: 1.85 kg **Average: 2.2 kg CO_2e / dm^2 display area** PC display: 2.4 kg Laptop: 3.3 kg Tablet: 4.5 kg Smartphone: 6.8 kg

OSAT - Outsourced Semiconductor Assembly & Test
HDI - High Density Interconnect

Key challanges

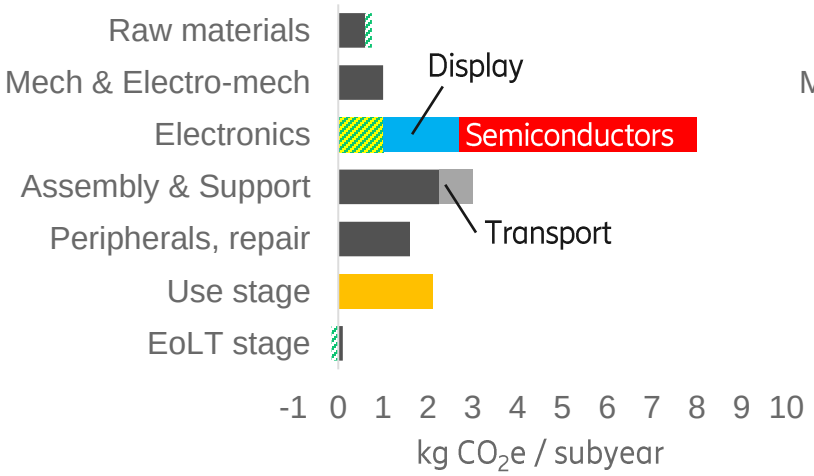
- **Choose relevant materials and processes**
- **Collect emission factors (EF) covering the intended scope**
  - **Handling of upstream supply chain data**
    - Known and unknown data gaps (incl. yield factors, infrastrucutre)
    - Risk of double accounting or "forgetting…"
  - **Quantification of the total product output to be able to create a robust average EF**
    - Product output can be sensitive information
  - **Allocation of data to various types of components/products**
    - Just one average do not work for all components/products

LCA "standard issues":

- Old generic data
- Variation in scope
- …
- …**Uncertainty**

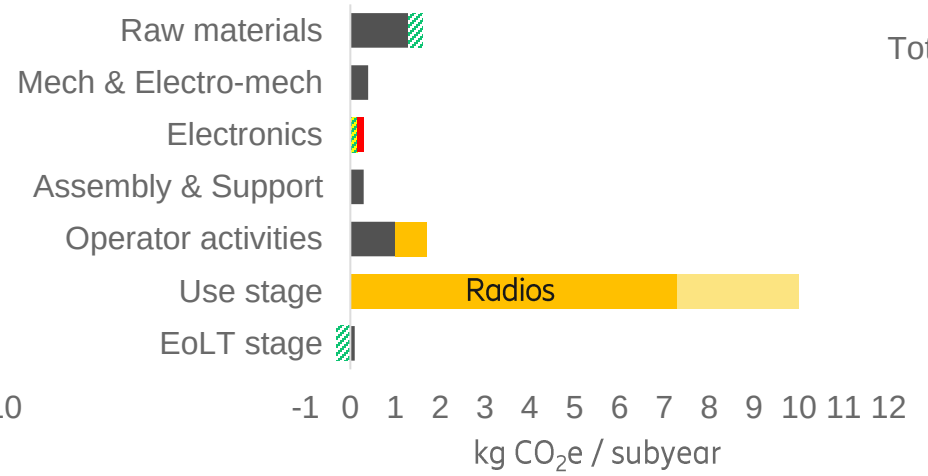
Simplified LCA of "a mobile subscription"

Smartphone & peripherals



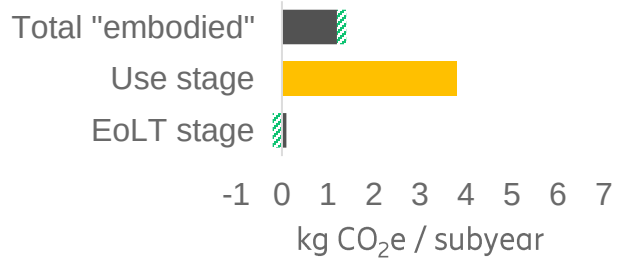
~15 kg CO_2e

Mobile network



~15 kg CO_2e

Data centers Servers

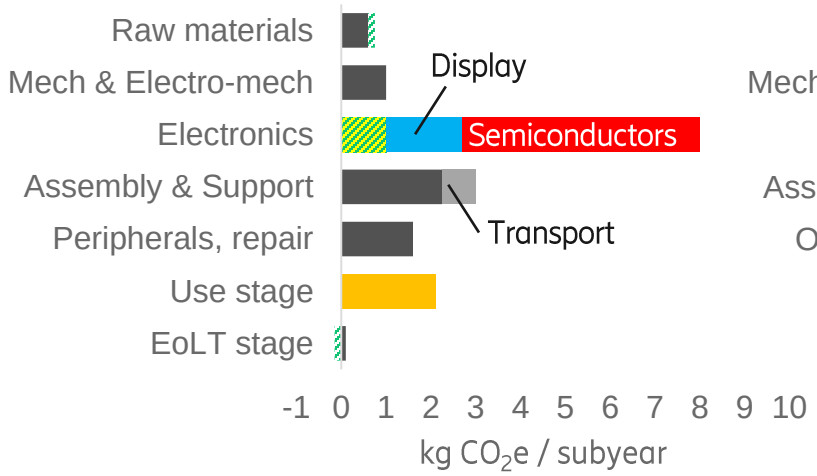


~5 kg CO_2e

Total ~35 kg CO_2e per subyear equals about: ~12 liter fuel

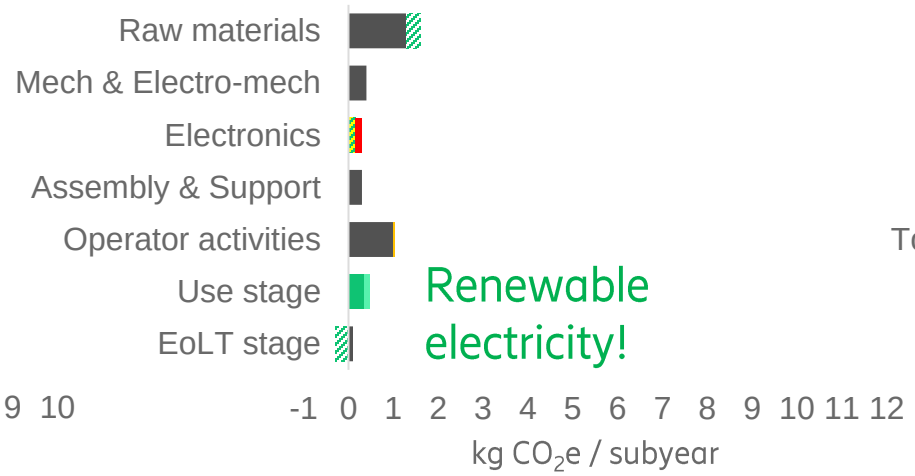
Simplified LCA of "a mobile subscription"

Smartphone & peripherals



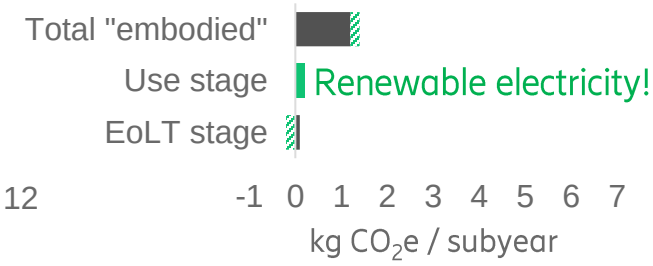
~15 kg CO_2e

Mobile network



~4 kg CO_2e

Data centers Servers

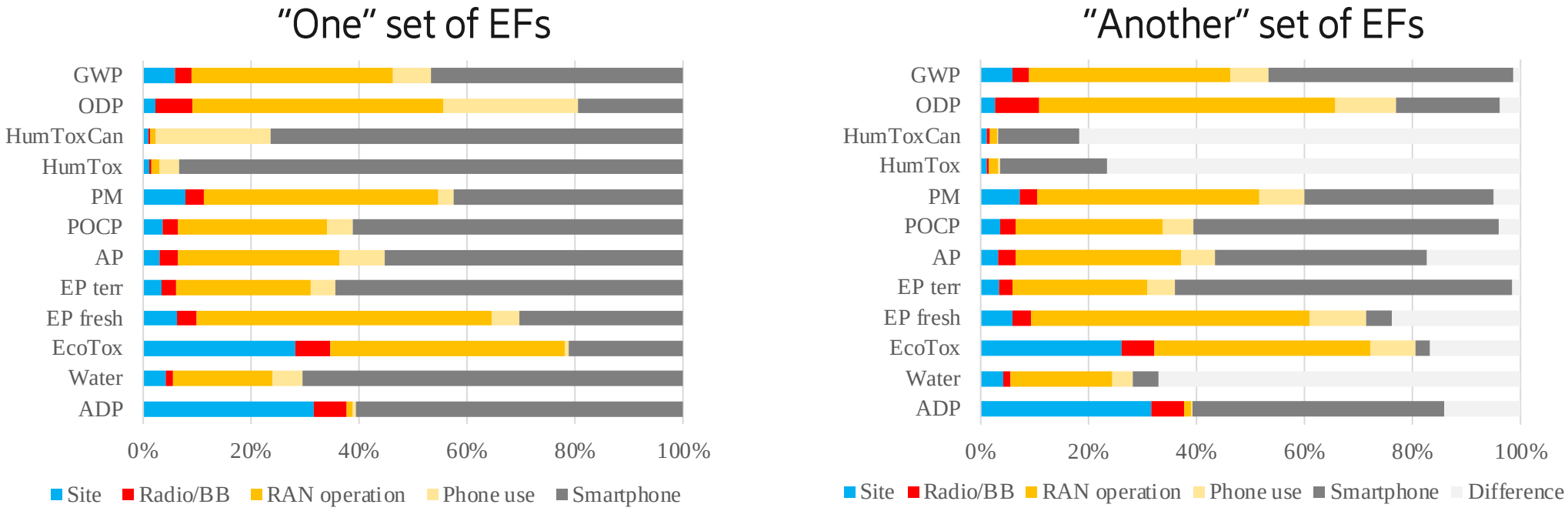


~1 kg CO_2e

Total ~20 kg CO_2e per subyear equals about: ~7 liter fuel

A lot more impact categories…

Emission factors can be created for any impact category



1) Network operation and/or mobile phone (smartphone) manufacturing is key
2) Gold and copper (in the phone/smartphone) mining and processing large in Toxicities
3) Steel and concrete in site infrastructure is large in a few categories

Material use per subyear

1 “half-stone”

1 spring clip

2 x 50 cl cans

2 x 20 cent EUR coins

0.25% of a ring

0.1% – 0.01% of a EV battery

(up to 1% of a car lead battery)

		Global share:		Key part:
Concrete	1.5 kg	0.04 %	0.3 kg CO_2e	BS sites (towers)
Steel	0.25 kg	0.08 %	0.6 kg CO_2e	
Lead	*0.1 kg*	*6%*	*0.2 kg CO_2e*	
Aluminum	0.03 kg	0.3 %	0.5 kg CO_2e	Radios
Copper	0.01 kg	0.3 %	0.06 kg CO_2e	Smartphones
Gold	0.00001 kg	2 %	0.26 kg CO_2e	
Cobalt	0.004 kg	16 %		
Lithium	0.0005 kg	2 %		
...$LiCoO_2$	...0.01 kg		...0.13 kg CO_2e	
Indium	0.000003 kg	1.5 %		

Cobalt and lithium shares decrease fast
due to the rapid increase of electronic vehicles batteries