# Sustainable Electronics: Challenges, Opportunities, and Instruments

BarCamp des GDRs SOC2 et Sécurité 13-15 décembre 2023

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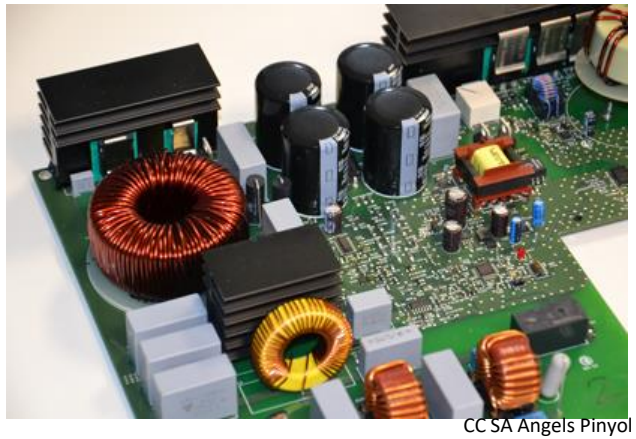
# Scope

- What is the electronics market?
- How does electronics affect sustainability? (focus on environment and climate)
- How can we act?

# Electronics Market and systems

# Electronic Devices

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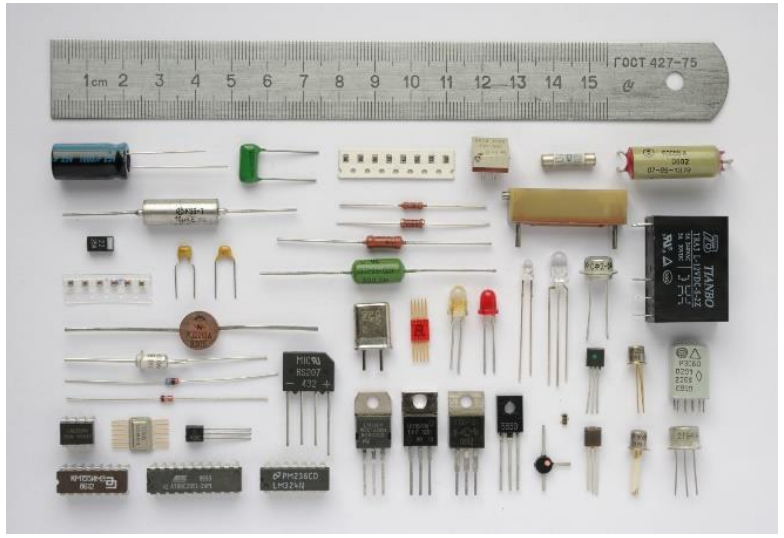

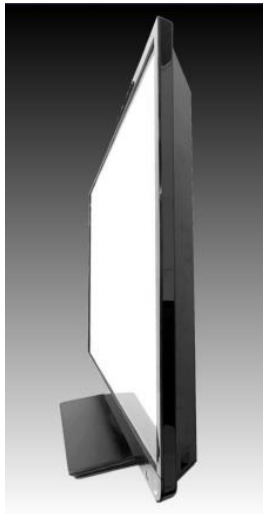

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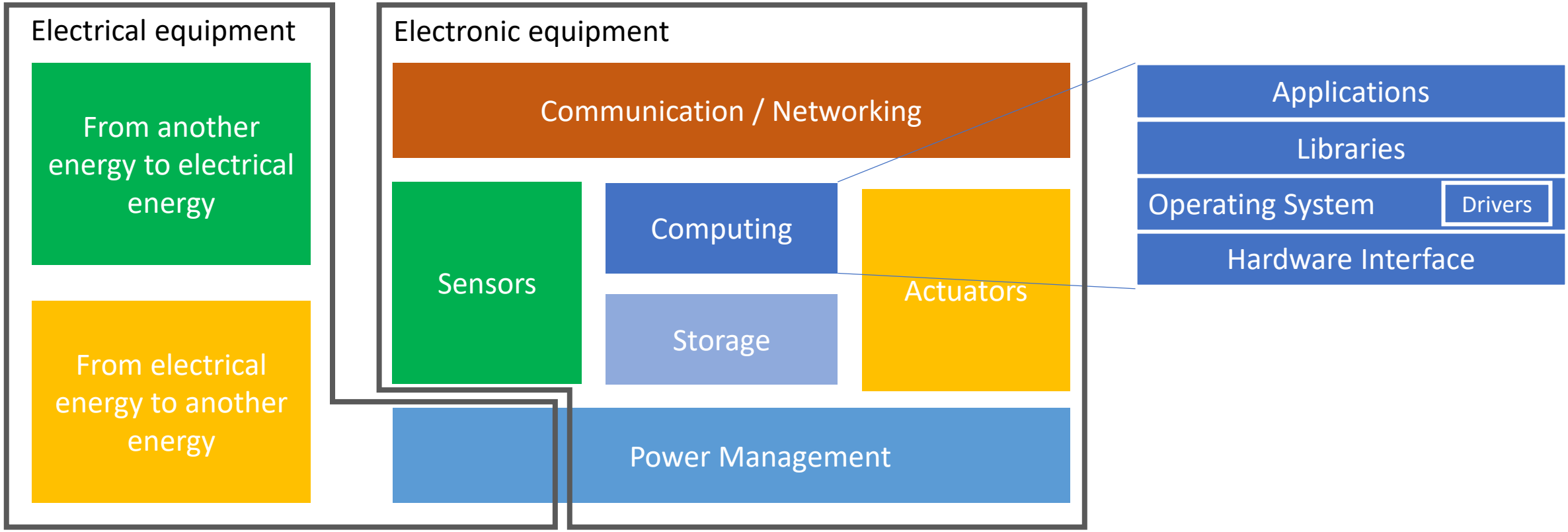
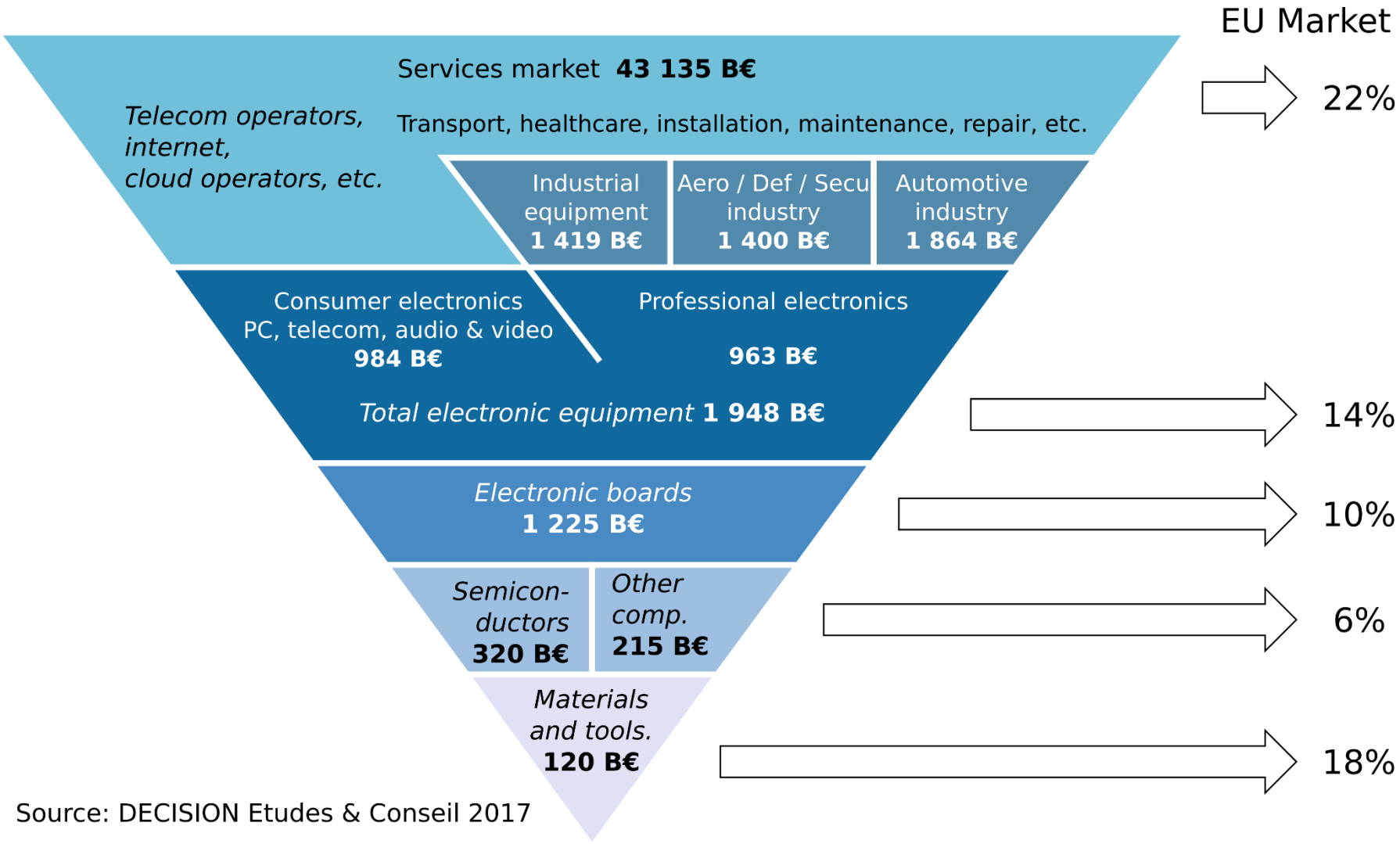
# Electronic and Electrical Equiment (EEE)



# Electronics market and Europe (in 2017)




Source: DECISION Etudes & Conseil 2017

# Electrical and Electronic Equipments

Air purifier
Air conditioner
Alarm clock
Backup charger
Bread maker
Banknote counter
Blender
Bluetooth speaker
Bulb
Calculator
Car toy
Ceiling fan
Chandelier
Clock
Clothes dryer
Coffee maker
Computer
Copier
Curling iron
Digital camera
Dishwasher
Doorbell camera
Drill
Dvd player
Earphones
Electric frying pan
Electric grill
Electric guitar
Electric pencil sharpener
Electric razor
Exhaust fan
External hard drive
Fan
Facial cleansing machine
Fax
Fish tank
Floor lamp
Game controller
Garage
Grandfather clock
Hair dryer
Headset
Inkjet printer
iPod
Iron
Juicer
Kettle
Kitchen scale
Hair straightening machine
Laser printer
Lawn mower
Lift
Meat grinder
Microphone
Microwave
Mixer
Monitor
Mosquito racket
Mouse
Mp3 player
Oil-free fryer
Piano
Oven
Plotter
Pressure cooker
Printer
Projector
Radiator
Radio
Reading lamp
Refrigerator
Remote control
Rice cooker
Safe
Robotic vacuum cleaner
Sandwich maker
Scale
Scanner
Sewing machine
Smart television
Smartphone
Speakers
Tablet
Television
Timer
Toaster
Torch
USB drive
Vacuum cleaner
Walkie-talkie
Washing machine
Watch
Water pumps
Water purifier
Wall fan
Water heater
Webcam
Wifi modem

List from 7esl.com

# Electrical and Electronic Equipments

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Washing machine
Watch
Water pumps
Water purifier
Wall fan
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Webcam
Wifi modem

**ICT main devices**

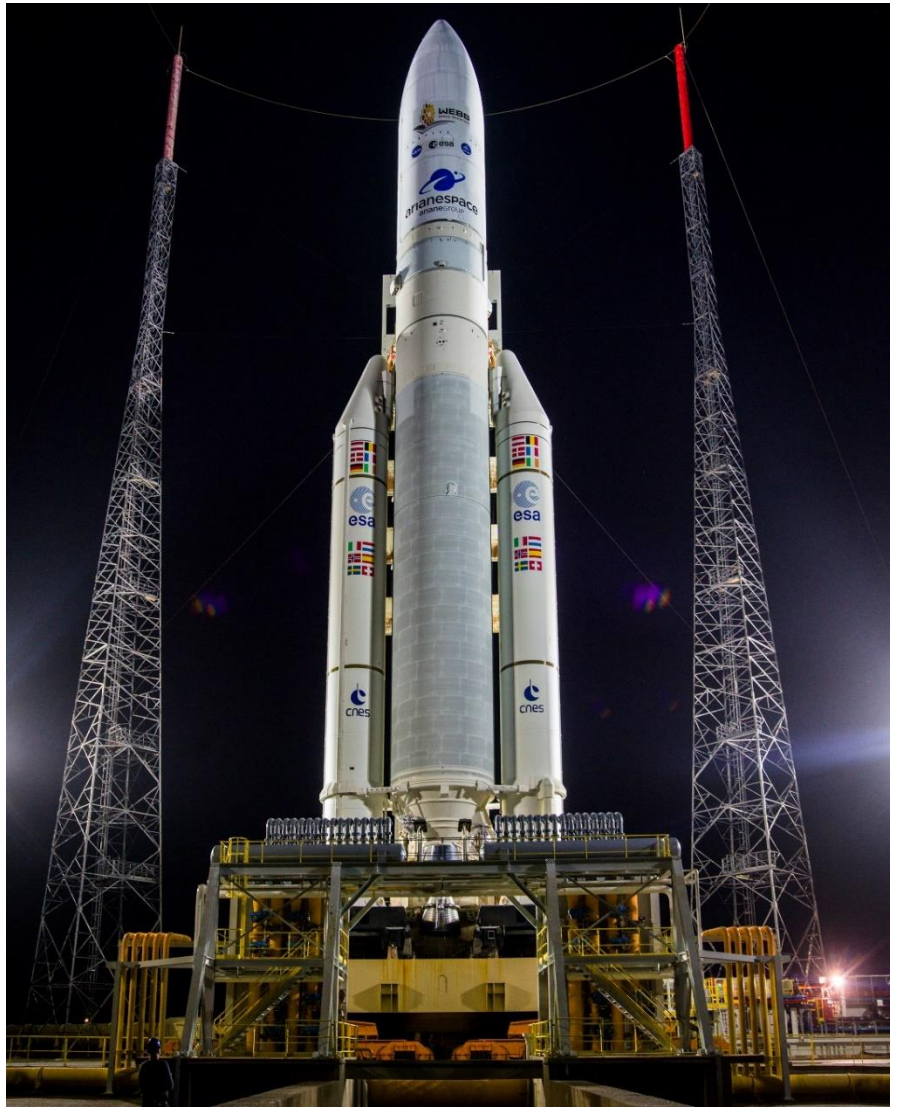
List from 7esl.com

# Electrical and Electronic Equipments

… and

xG Base stations
Cars
Boats
Planes
Trains
Tramways
Busses
Windmills
Power plants
Satellites
Rockets
Supercomputers
Data centers
…

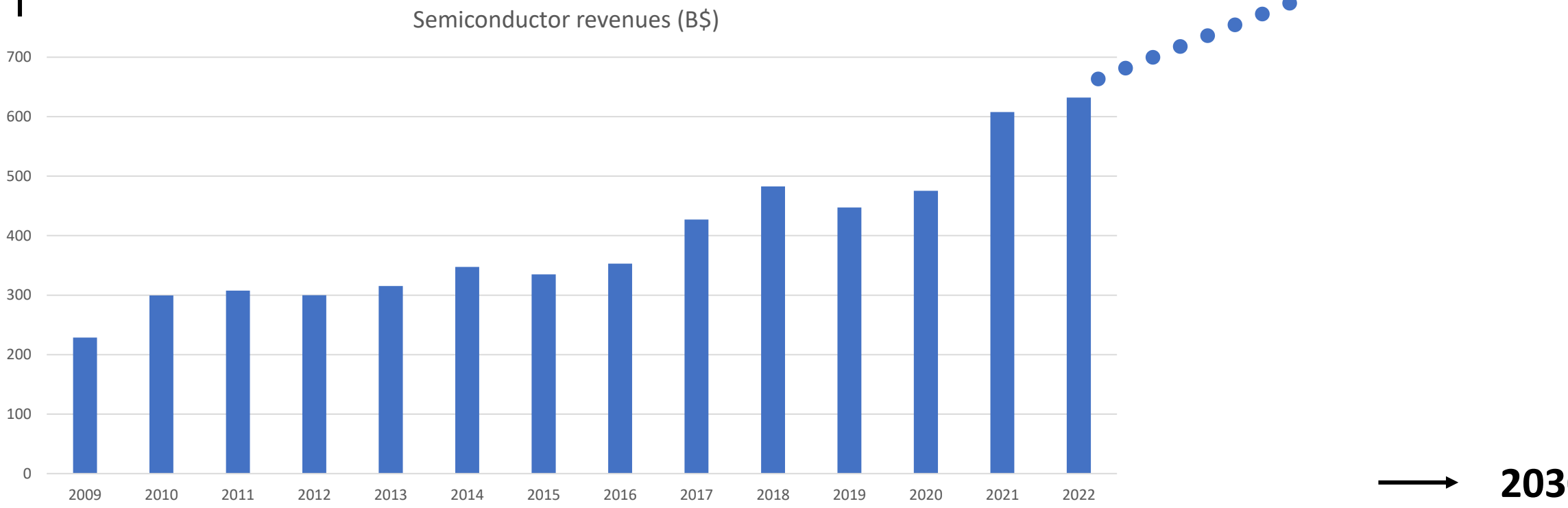
CC-BY-SA Aynamankajan




CC-BY NASA's James Webb Space Telescope from Greenbelt, MD, USA

# Semiconductor industry revenue

**1 trillion $**



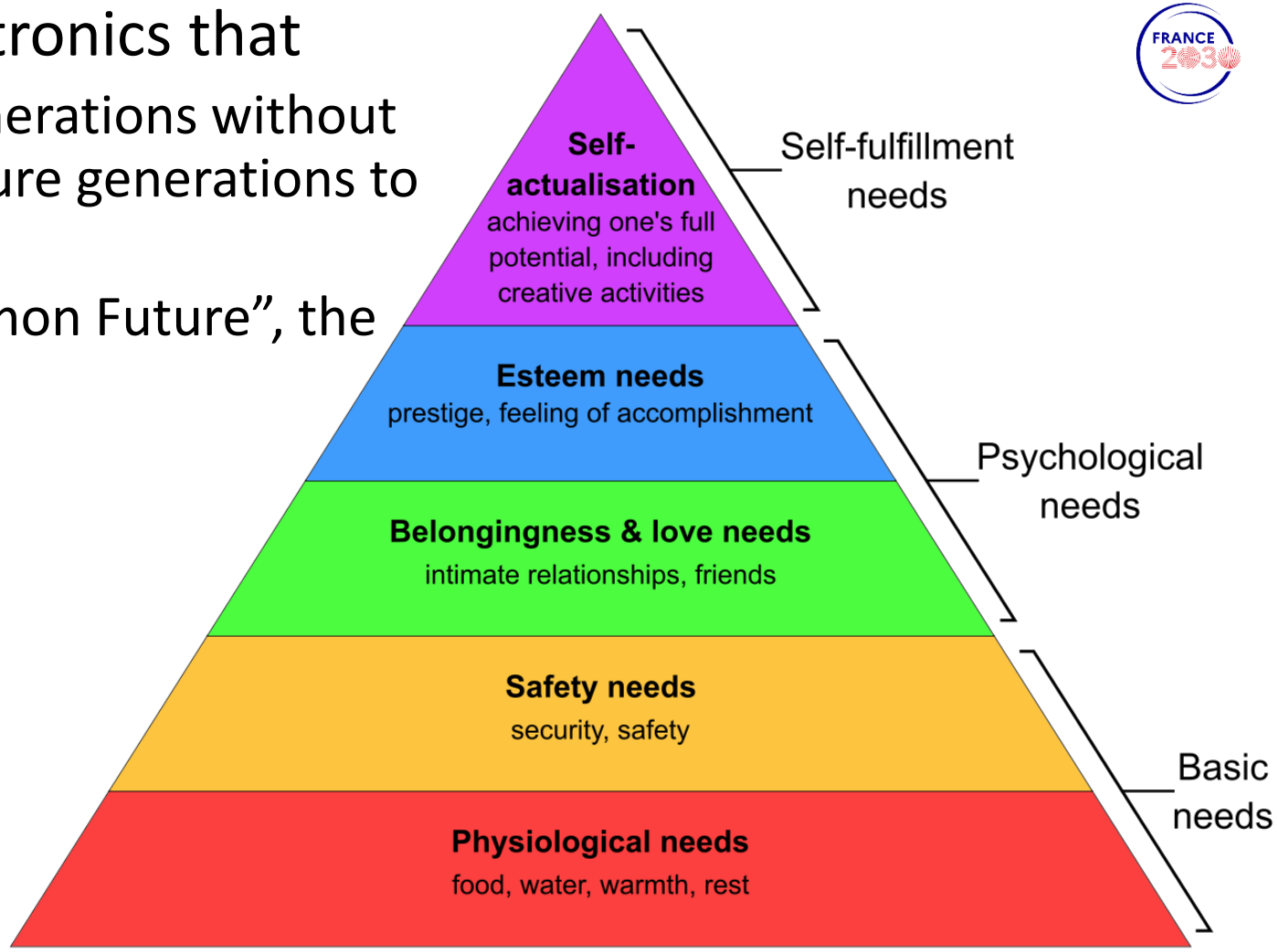

Numbers: Statista

# Electronics and Sustainability

# What is sustainable electronics?

- Sustainable electronics is electronics that
  - meets the needs of present generations without compromising the ability of future generations to meet their own needs.
  - Brundtland report – “Our Common Future”, the United Nations, 1987

- 3 pilars
  - Environmental
  - Social
  - Economic

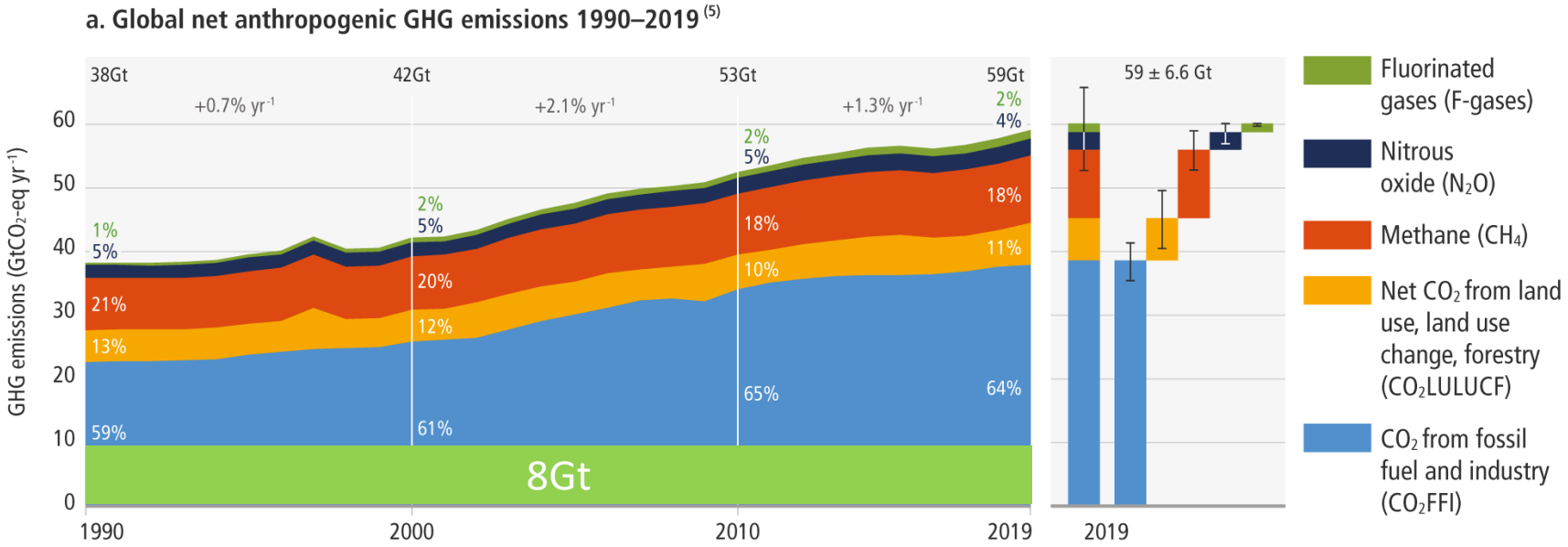



Maslow’s pyramid

# Human carbon impact

- Human GHG emissions reach 60Gt/year
- To respect the 1.5°C scenario of the Paris Agreement, emissions must reach 8Gt/year by 2050, i.e. **a reduction of ~7× by 2050**

**Global net anthropogenic emissions have continued to rise across all major groups of greenhouse gases.**




*The Closing Window: Climate crisis calls for rapid transformation of societies, UN environment program 2022*

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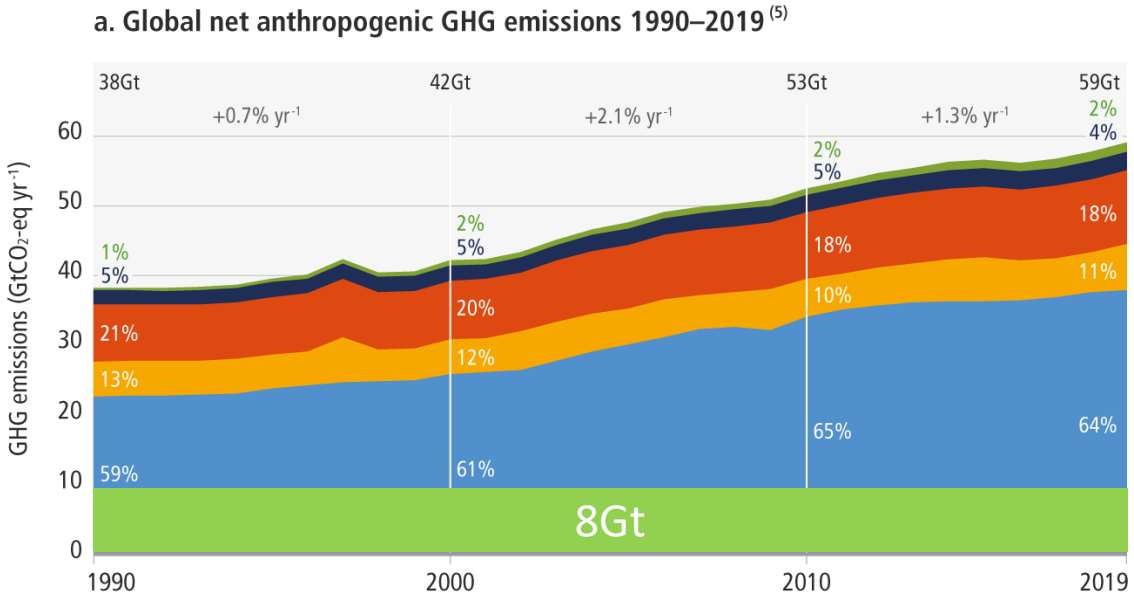


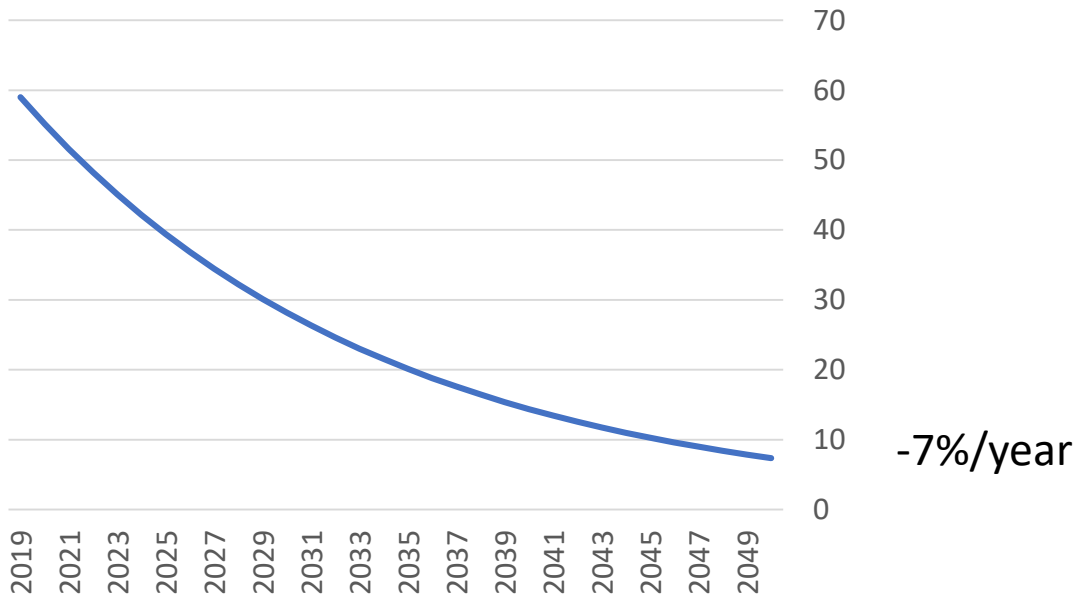


-7%/year

# Semiconductors and GHG emissions

- The manufacture of integrated circuits has emitted 76Mt CO2eq in 2021 (only scopes 1 and 2), an **increase of 13% from 2020 to 2021.**

| Year | Semiconductor Market with Foundries | | |
|---|---|---|---|
| | Scope 1 | Scope 2 | Total |
| 2020 | 26.84 $MtCO_2e$ | 40.96 $MtCO_2e$ | 67.8 $MtCO_2e$ |
| 2021 | 30.56 $MtCO_2e$ | 45.93 $MtCO_2e$ | 76.5 $MtCO_2e$ |

*Maxime Pelcat. GHG emissions of semiconductor manufacturing in 2021. Research Report. 2023. ⟨hal-04112708⟩*

# How do EEE help sustainability?

- All energy transitions/shifts heavily employ electronics and electrical equipments (EEE)
  - Electric cars, renewable energies from windmills, solar panel, heat pumps…
- Energy optimization heavily relies on EEEs
  - Smart grids, smart buildings, smart cities…

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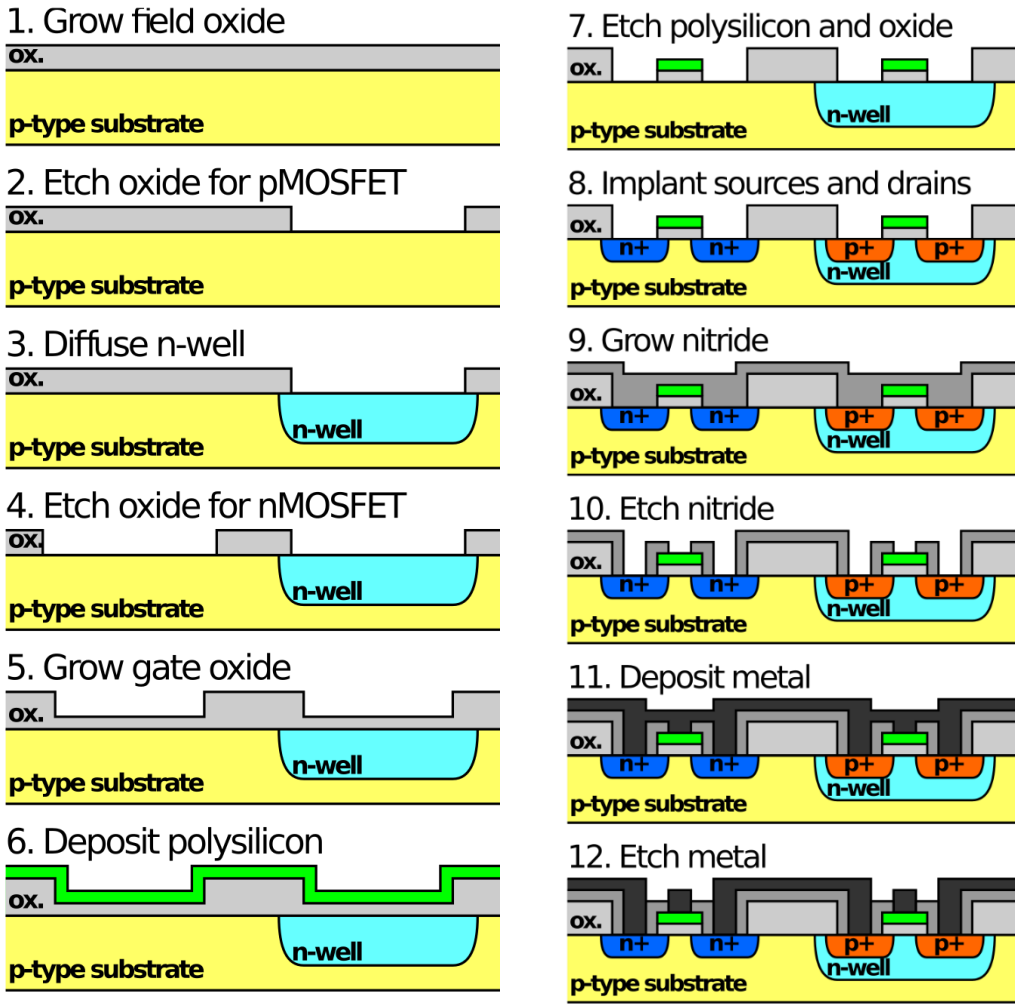
# How do EEE hinder sustainability?

(focusing on environmental impacts)

- Production of EEEs
  - Requires rare material (abiotic resource depletion)
  - Emits greenhouse gases
  - Requires much water
- Usage of EEEs
  - Requires energy
- End-of-life of EEEs
  - Emits e-wastes that pollute water and soils

Author: Laconicon

# Semiconductors and GHG emissions



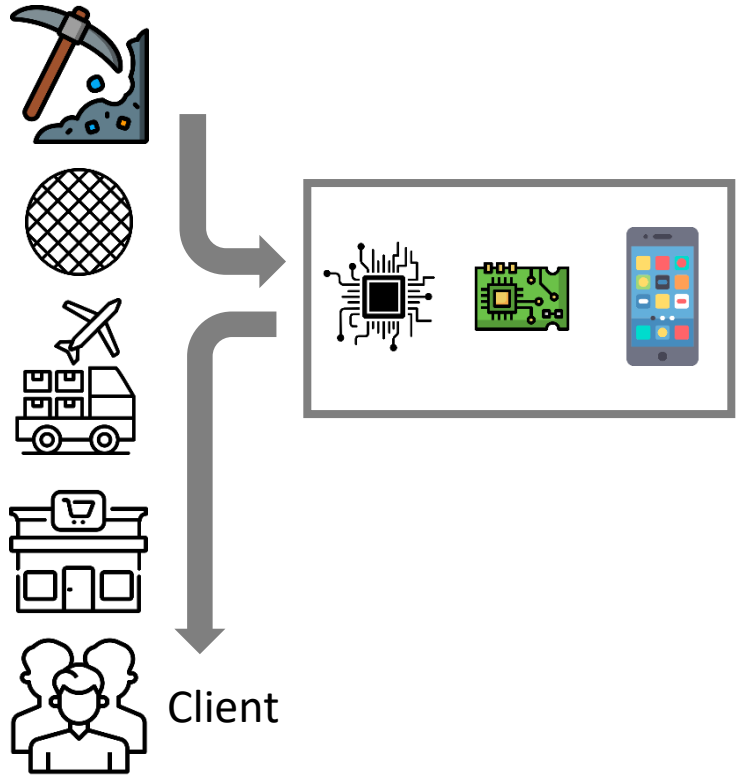

- Scope 1 emissions: F-gases
  - F-gases are used for cleaning and etching, as well as for heat pumps and refrigerants
  - 1kg of $SF_6$ ⇔ 23 tons of $CO_2$

*Bartos, S. C., & Burton, C. S. (2002). PFC, HFC, NF3, and SF6 emissions from semiconductor manufacturing. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 1-13.*

- Scope 2 emissions: electricity
  - From 60g $CO_2$e/kWh to 1kg $CO_2$e/kWh

# Semiconductors and GHG emissions

- Scope 3 **upstream** emissions
  - Mining materials
  - Smelting
  - Refining
- Scope 3 **downstream** emissions
  - Transporting products
  - Using products
  - End-of-life

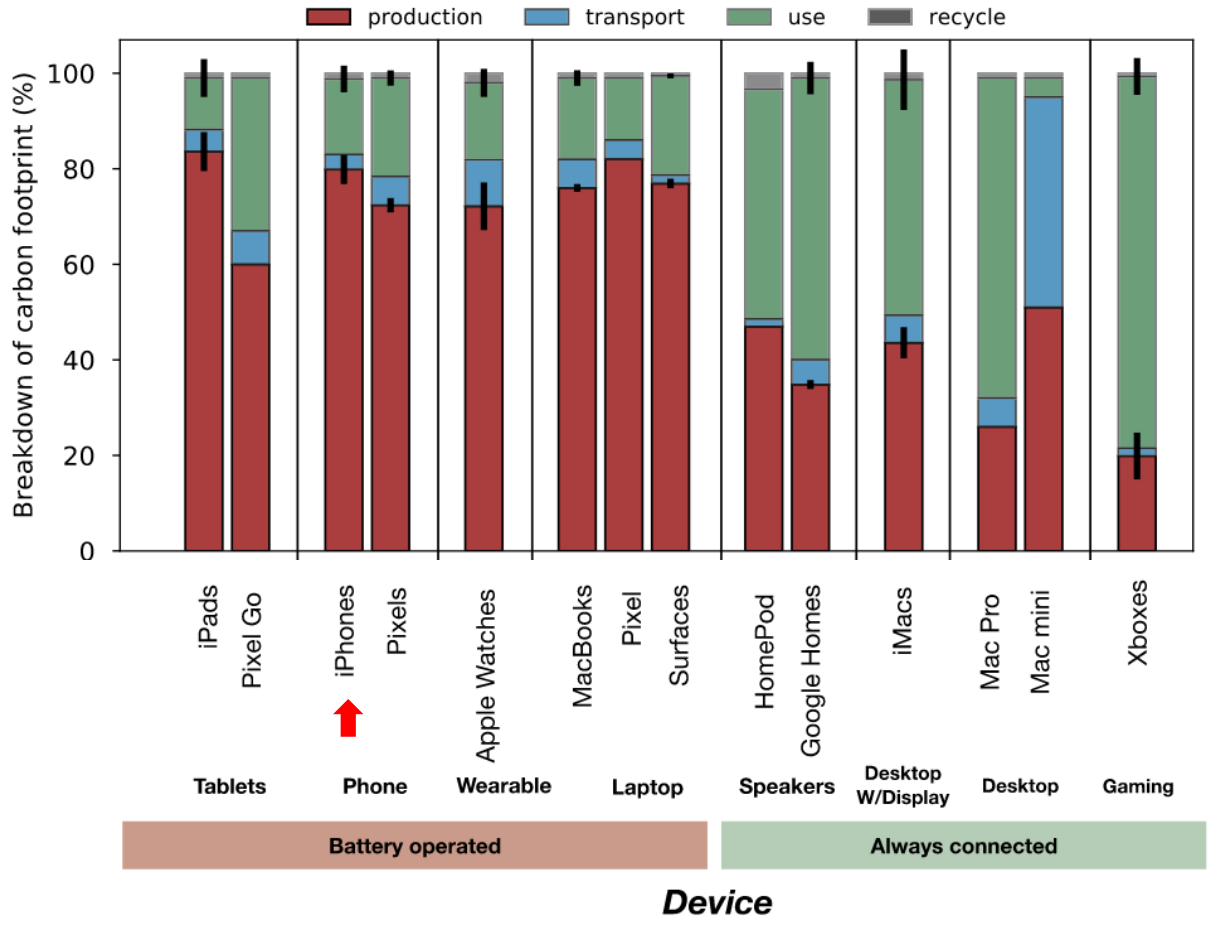



- Impacts of electronics are increasingly well understood

*Greenhouse Gas Protocol, World Resources Institute, Revised edition, 2015*

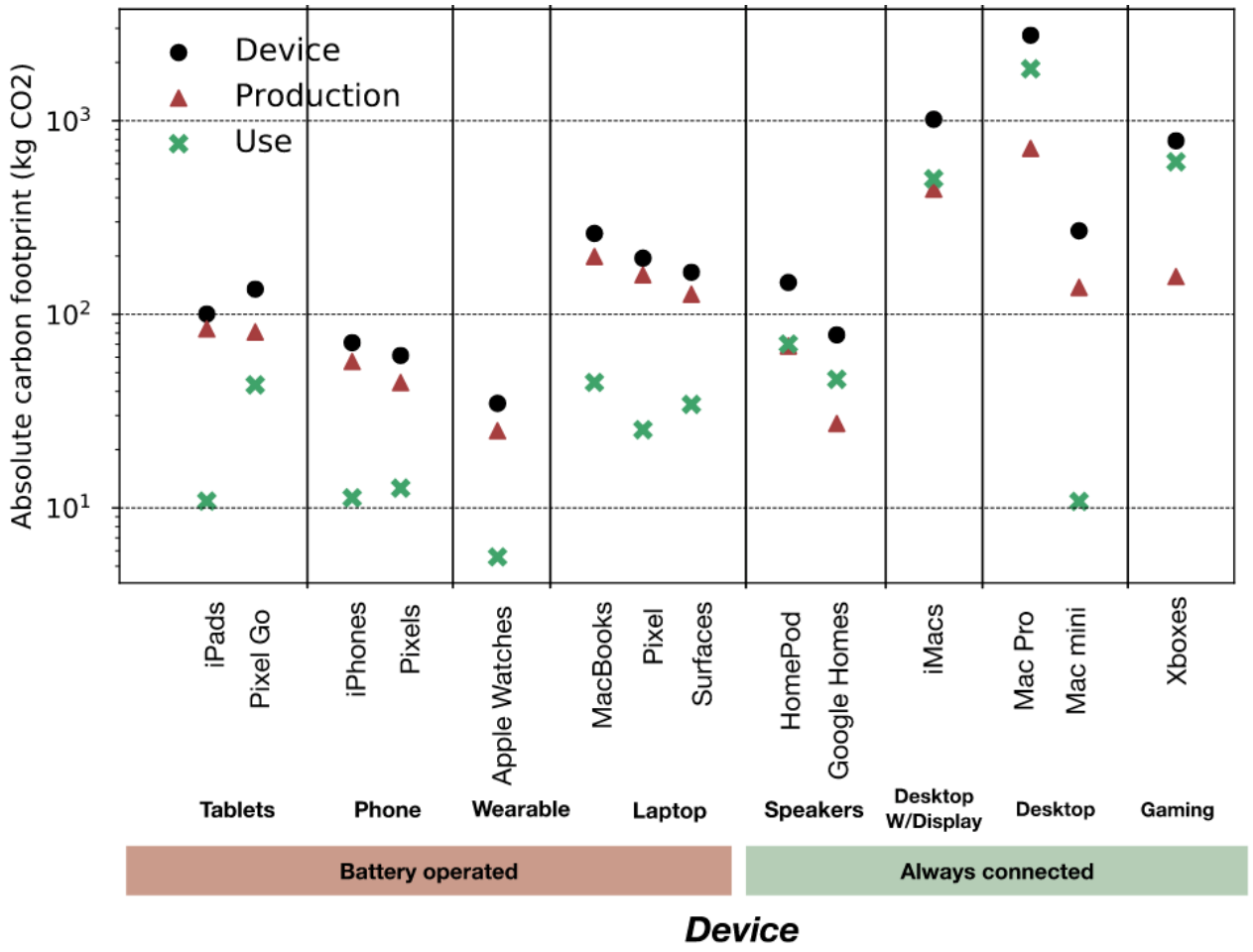
# Semiconductors and GHG emissions

- 85% of a cell phone's GHG emissions come from manufacturing




*Gupta, U., Kim, Y. G., Lee, S., Tse, J., Lee, H. H. S., Wei, G. Y., ... & Wu, C. J. (2022). Chasing carbon: The elusive environmental footprint of computing. IEEE Micro.*

# Absolute carbon emissions of devices

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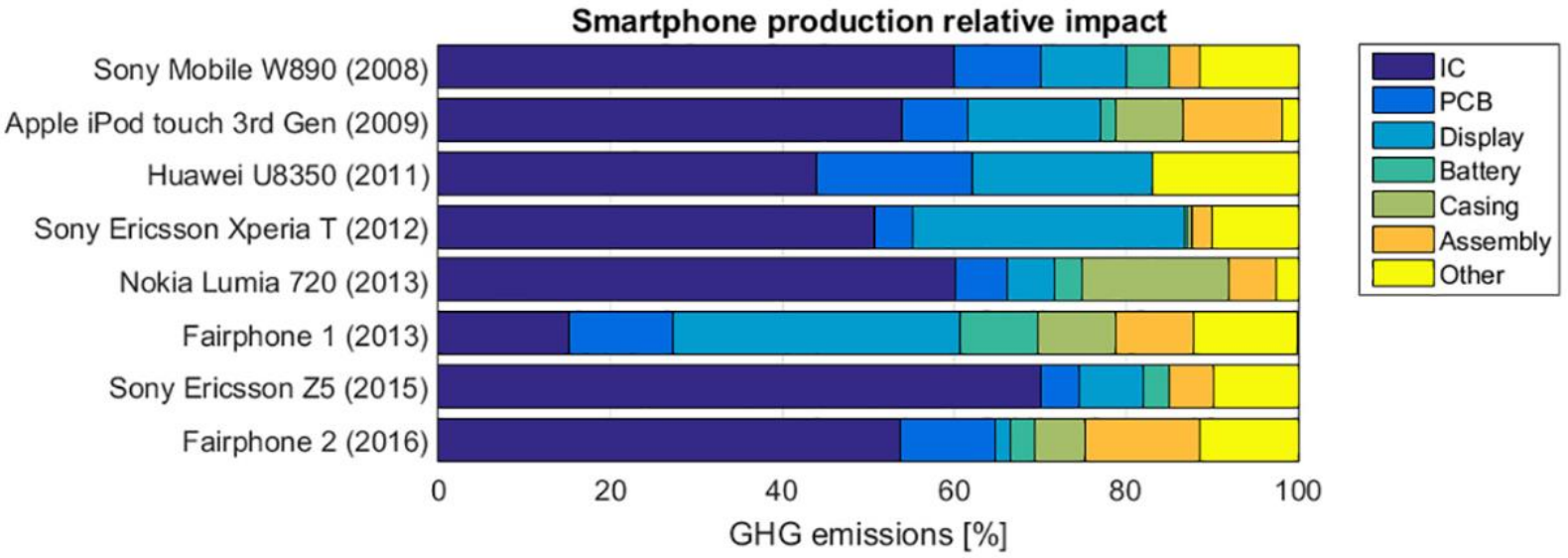
# Semiconductors and GHG emissions

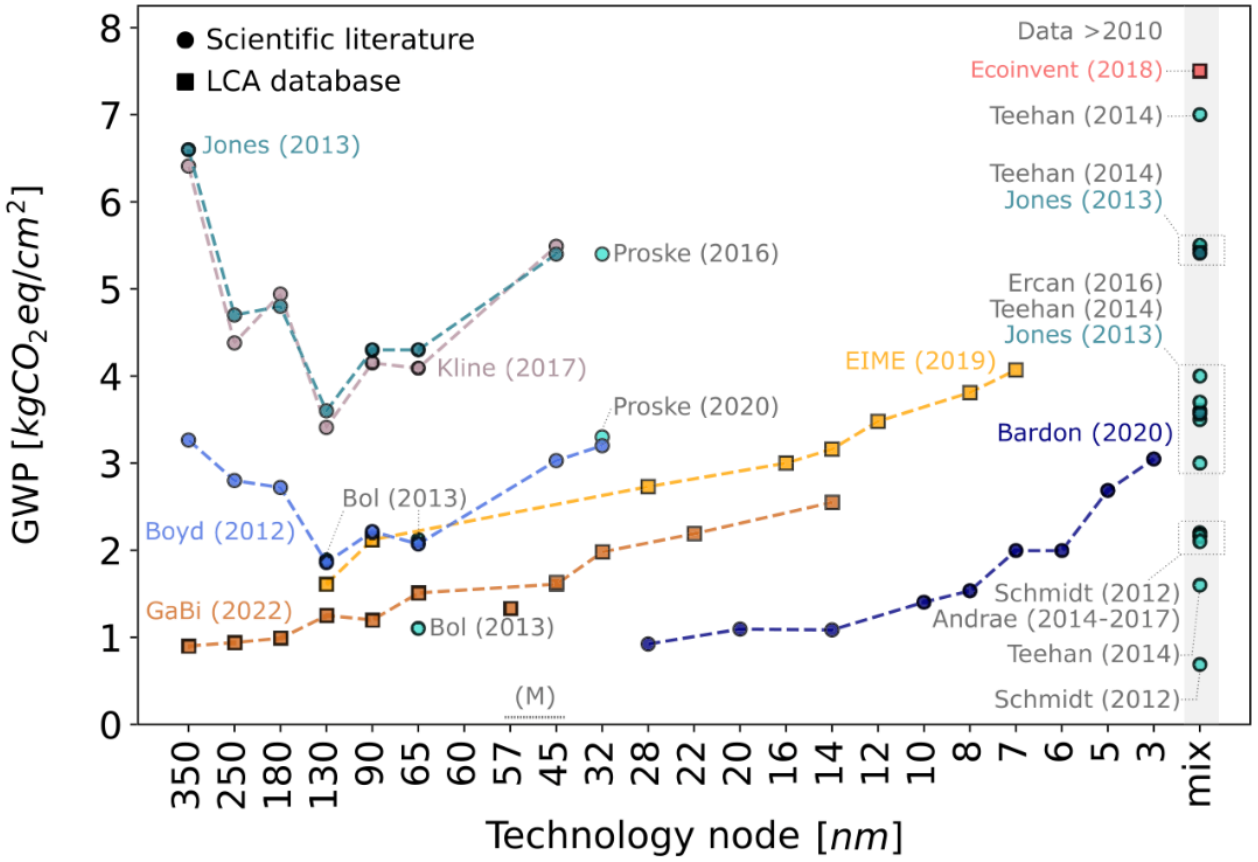
- The manufacture of integrated circuits is the primary cause of cell phone emissions




*Louis-Philippe, P. V. C., Jacquemotte, Q. E., & Hilty, L. M. (2020). Sources of variation in life cycle assessments of smartphones and tablet computers. Environmental Impact Assessment Review, 84*

# Semiconductors and GHG emissions

- Product lifecycle analysis is a complex science, requiring a detailed understanding of the scope and assumptions involved




*Pirson, T., Delhaye, T. P., Pip, A., Le Brun, G., Raskin, J. P., & Bol, D. (2022). The environmental footprint of IC production: Review, analysis and lessons from historical trends. IEEE Transactions on Semiconductor Manufacturing.*

# Electronics-generated waste

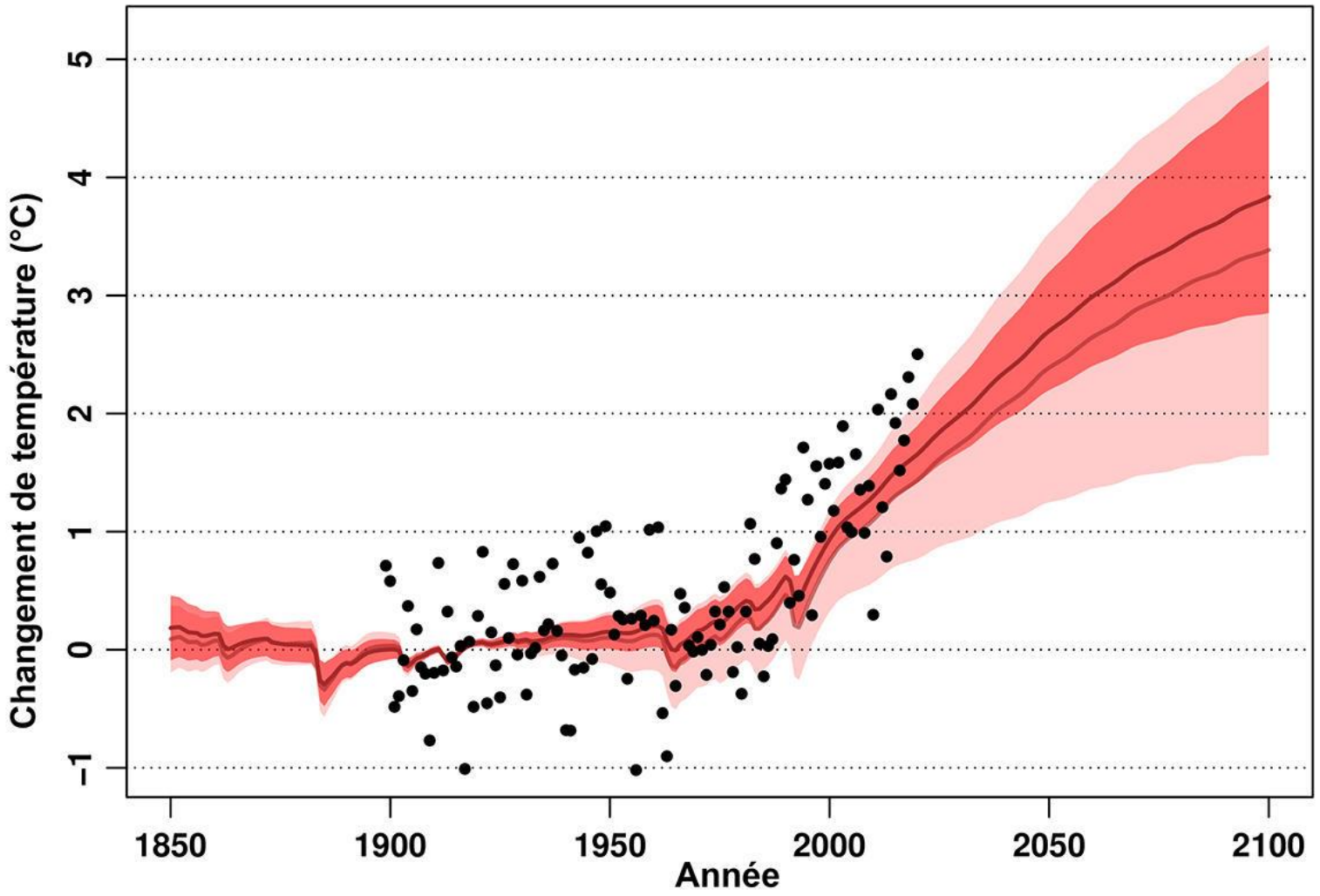
- E-waste
  - One of the fastest-growing waste categories, growing at a rate of 3–5% per year → includes *product housing*
  - In 2016, 44.7 million tons of e-waste were generated in the world , 6.1 kg per person; in 2019: 53.6 million tons
  - “Only 17.4 per cent of 2019’s e-waste was collected and recycled.” Global E-waste Monitor 2020




*Ilankoon, I. M. S. K., Ghorbani, Y., Chong, M. N., Herath, G., Moyo, T., & Petersen, J. (2018). E-waste in the international context – A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery. Waste Management, 82, 258-275.*

# How can we act?

# Global Warming, in France




*Aurélien Ribes et al. 2022, « Earth Syst. Dynam. », 13, 1397-1415 (CC BY-4.0)*

*Prediction for an intermediate scenario in which carbon emissions neither increase nor decrease drastically*

# From Local Decisions to Global Impacts

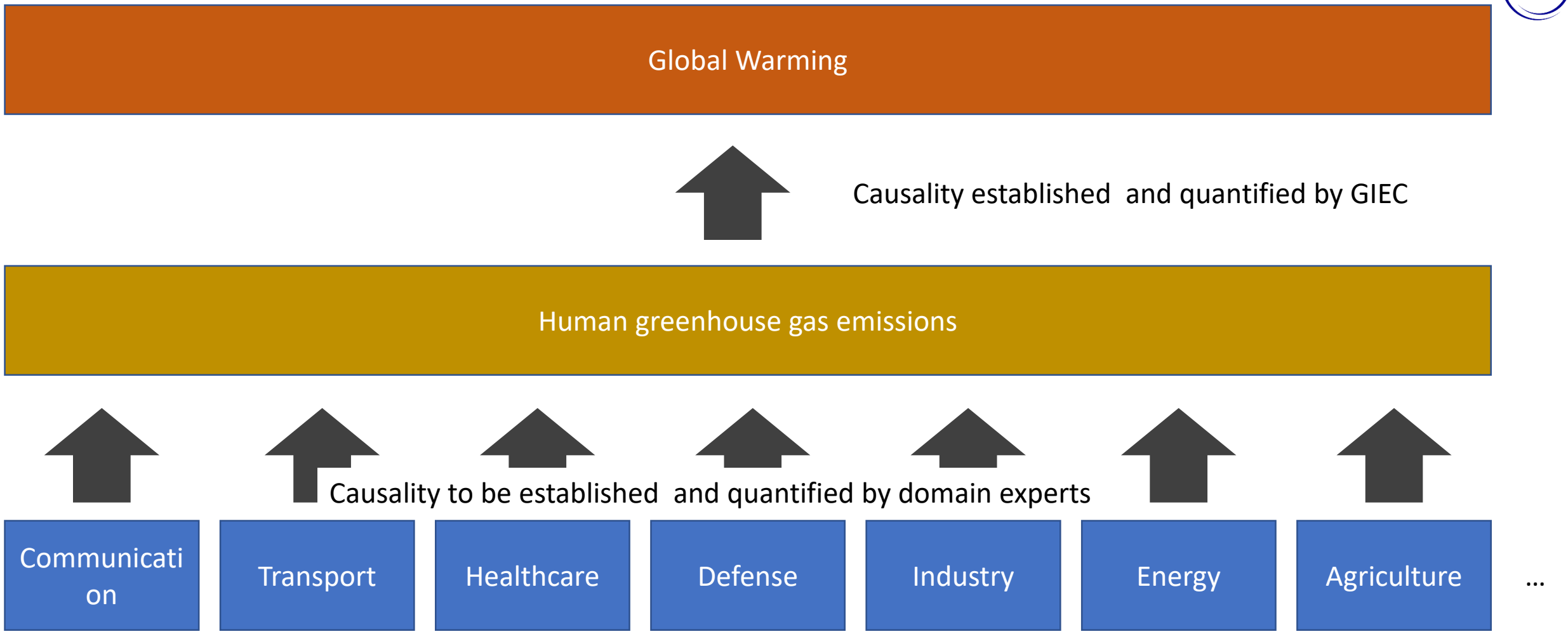
Global Warming

Causality established and quantified by GIEC

Human greenhouse gas emissions

Communication | Transport | Healthcare | Defense | Industry | Energy | Agriculture | …

# From Local Decisions to Global Impacts



# Some solutions – Research needed!

- Life cycle analysis
- 3R: Repair, Reuse, Recycle
- New fabrication technologies
  - PCB, IC, other components
- Better energy management

# How can we act?

- **Fight against obsolescence**
  - Mobile phones have a lifetime of 2.5 years, high-end processors 4.5 years
- Build **novel lengthened lifetime chips and systems**
  - upgradeable, reparable, reconfigurable, repurposable chip technologies
- **Understand the consequences of our design decisions**

# How can we act (as system architects)?

- Gather reliable, scientific numbers on electronics impacts, and evaluate their reliability
  - Life Cycle Analysis (LCAs)
  - **Attributional LCA**: aims to describe the environmentally relevant physical flows to and from a life cycle
  - **Consequential LCA**: LCA aiming to describe how environmentally relevant flows will change in response to possible decisions

*Finnveden, G., Hauschild, M. Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., ... & Suh, S. (2009). Recent developments in life cycle assessment. Journal of environmental management, 91(1), 1-21.*

# How can we act (as system architects)?

- Propose **new technologies** for repairable, reusable, reconfigurable, repurposable systems
- **Assess the real impact** of these new technologies in the field
- Help and foster the setup of **novel regulations** (incentives, taxes and quotas)

*Ashby, M. F. (2022). Materials and sustainable development. Butterworth-Heinemann.*

# How to act

- Carbon footprint reduction requires
  - **Transparency**
  - **Acting fast**
  - **Sharing information**

  → **Open source communities** (hardware and software) are key assets

- Electronics carbon footprint reduction requires
  - **True commitment to the goal**
  - **Technical competences**
  - **Research**

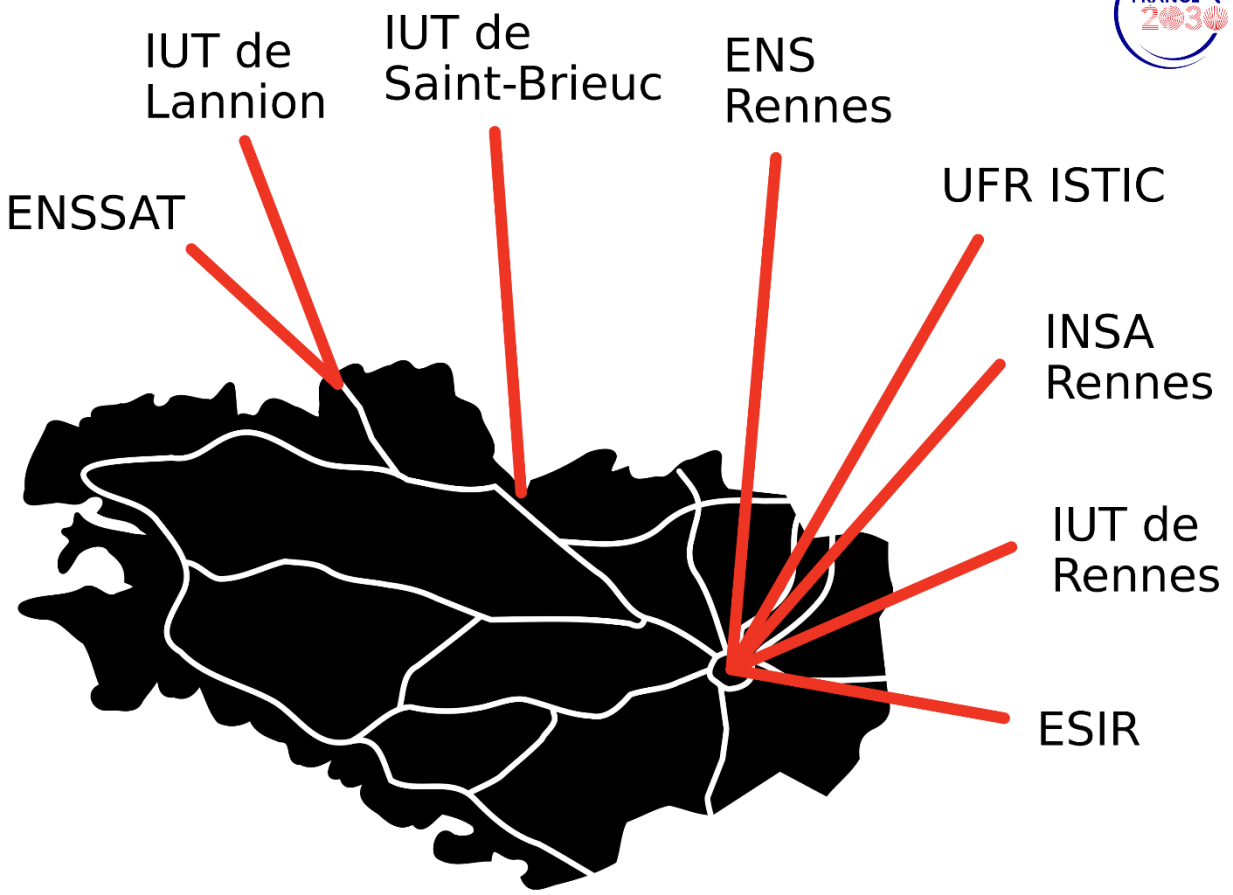
# The ESOS project

- **Electronics: Sustainable, Open and Sovereign**
- 2023-2028, 6.3M€, funded by France2030
  - **Sustainable:** meeting the needs of the present generation without compromising the ability of future generations to meet their own needs.
  - **Open:** a decentralized development model that publicly distributes the source code for open collaboration and peer production, known as "the open-source method."
  - **Sovereign:** the quality of a state being free and independent, determined solely by its own will within the limits of the higher principle of law, and in accordance with the collective purpose it is called to achieve.

# ESOS – 7 actions

- Attract pupils to electronics
- Train students to ESOS
  - Licence, master, doctorate
- Train professionals to ESOS
- Create **open teaching material**
- https://esos.insa-rennes.fr

- **30 industrial partners**
- **Open to collaborations!**



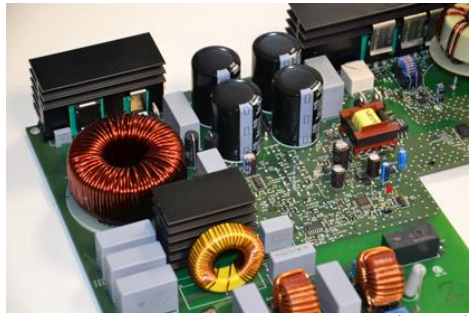
# Open Questions

- **comment faire communauté autour de cette question d'électronique soutenable?**
  - **Axe du GDR SOC2? Sous quelle forme?**
  - **qui inviter/impliquer? communautés efficacité énergétique, substrats matériels, outils de conception, IA embarquée, ???**
- **quelles questions sont-elles posées par ce sujet (technologiques et scientifiques)?**
  - **décisions locales, impacts globaux**
  - **réparabilité, réutilisabilité, allongement de la durée de vie, recyclabilité...**
  - **Interdépendance des technologies, business models et usages**





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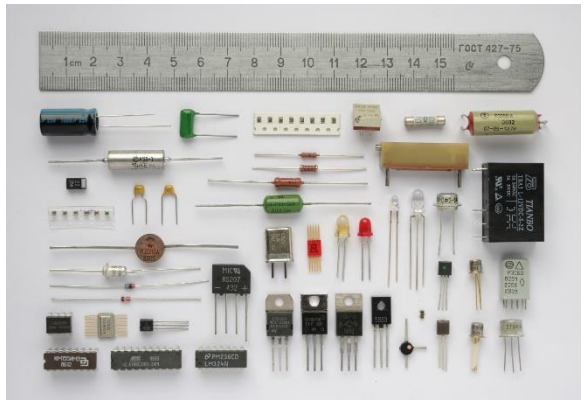

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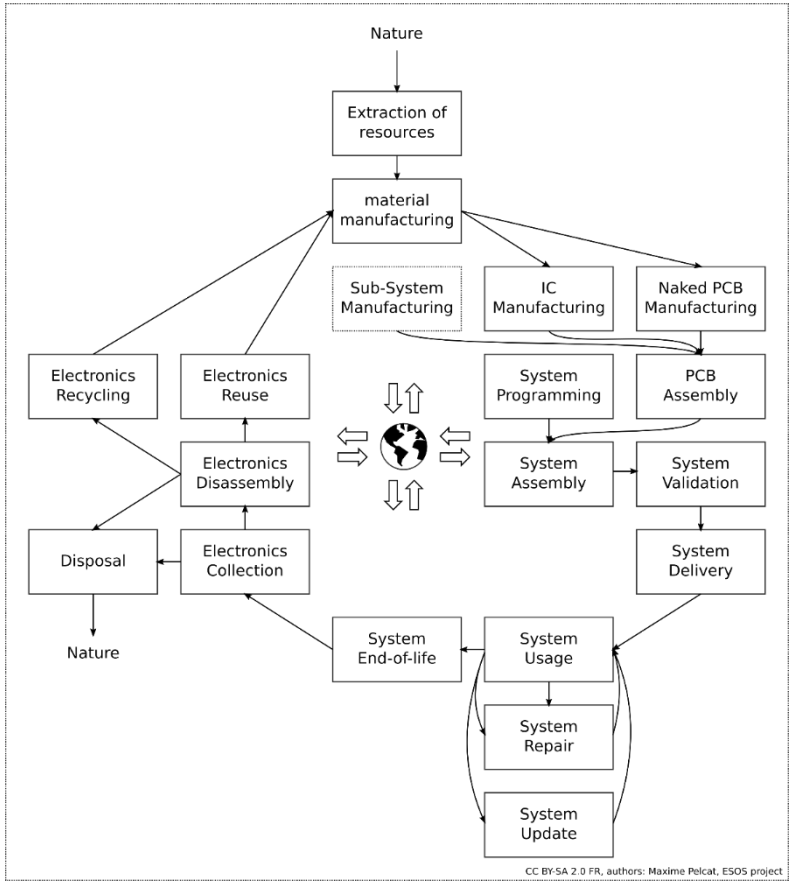
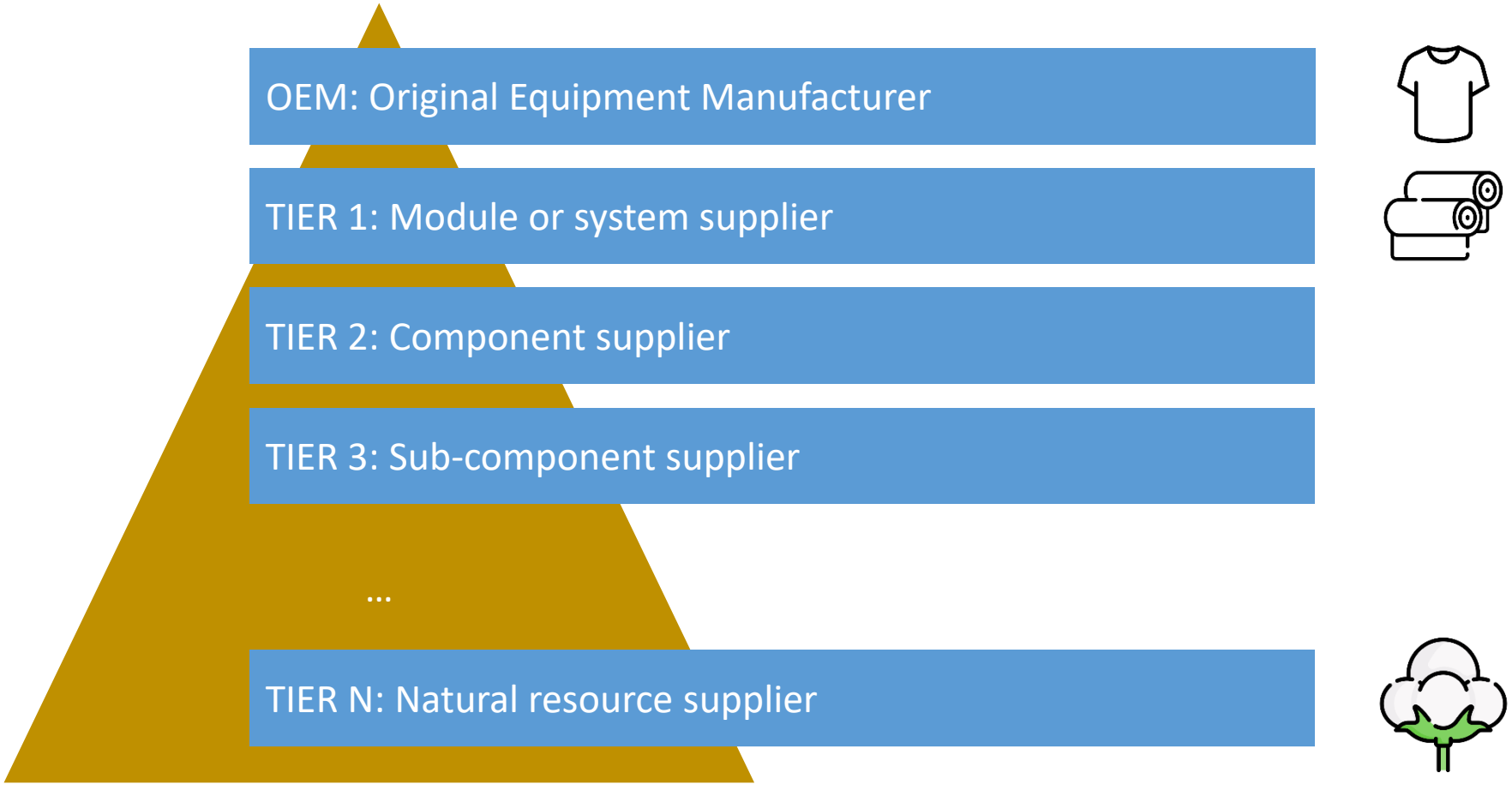


# Additional Slides

# Supply chain (in general)

- Industry employs a supply chain pyramid with Tiers

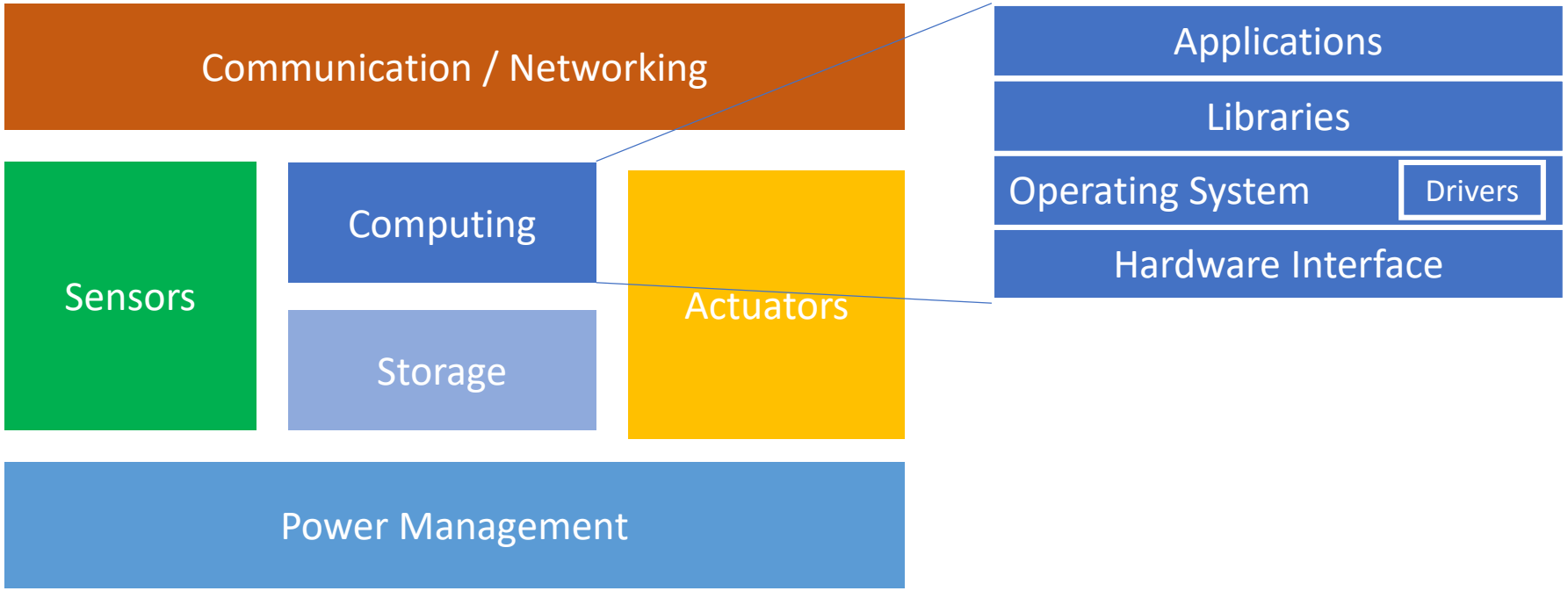



Flaticons: Mehwish, Freepik

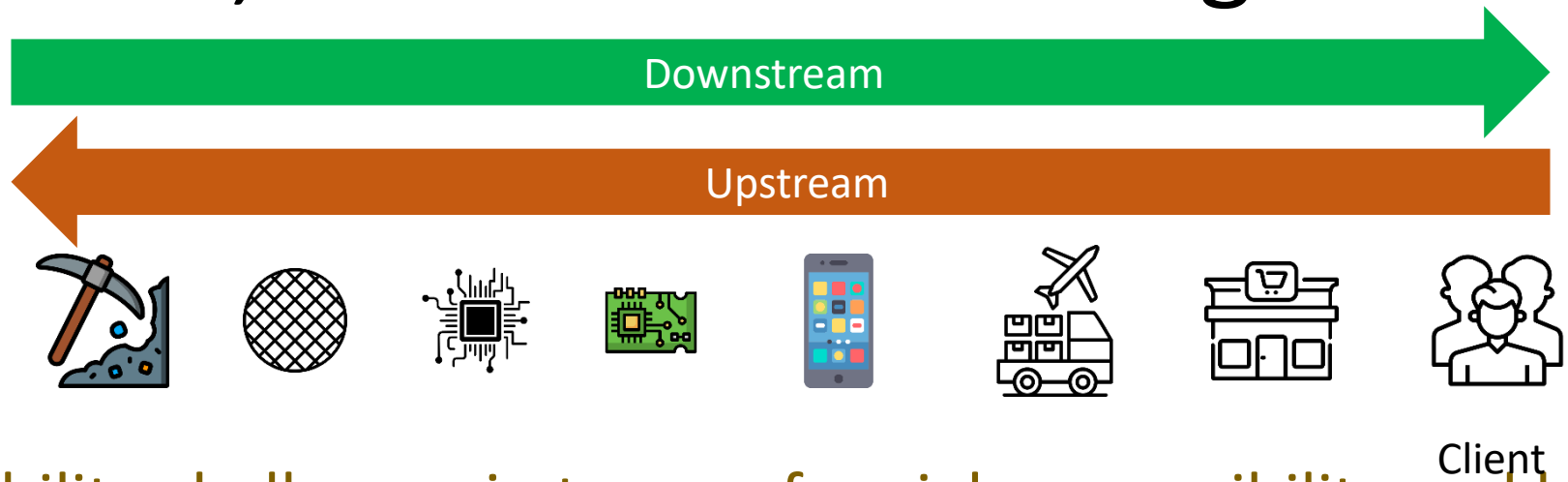
# The electronics industry supply chain

- Industry employs a supply chain pyramid with Tiers

# Structure of an embedded system



# Electronics, ethics and human rights




- Sustainability challenges in terms of social responsibility and human rights include:
  - Social standards for employees
  - Impacts on local communities
  - Impact on society