Arizona State University

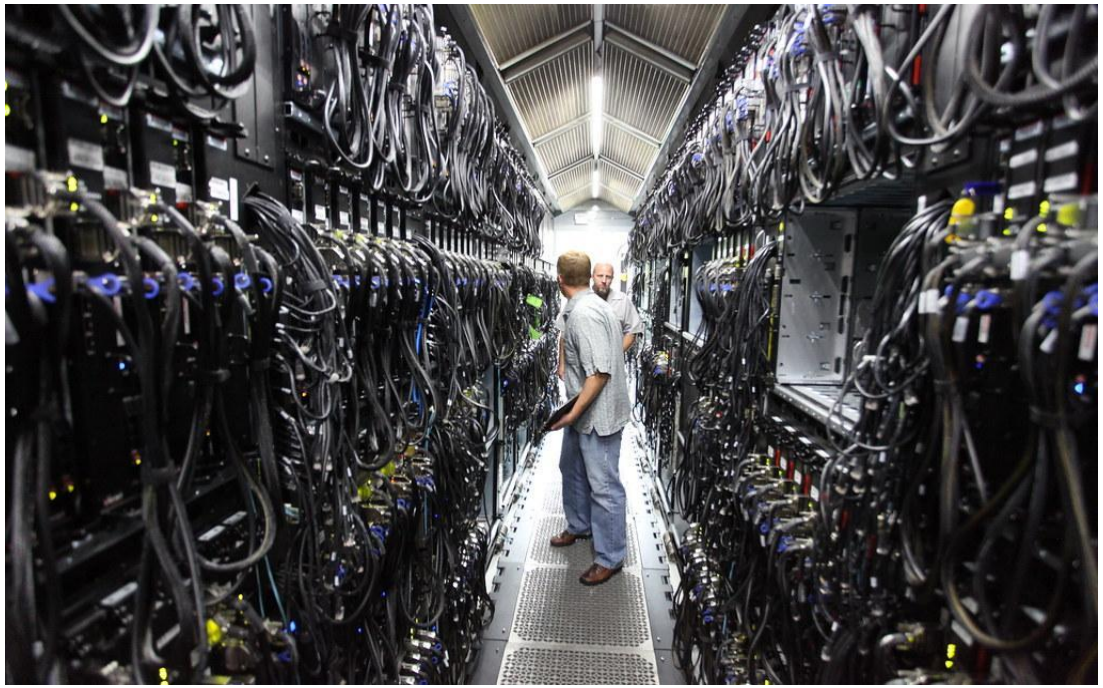
Beyond the Surface: The Necessity for Detailed Metrics in Corporate Sustainability Reports

Chetan Choppali Sudarshan, Aman Arora, and Vidya A. Chhabria

IGSC 2024

Information and Computing Technology (ICT)

Data Center and Networks

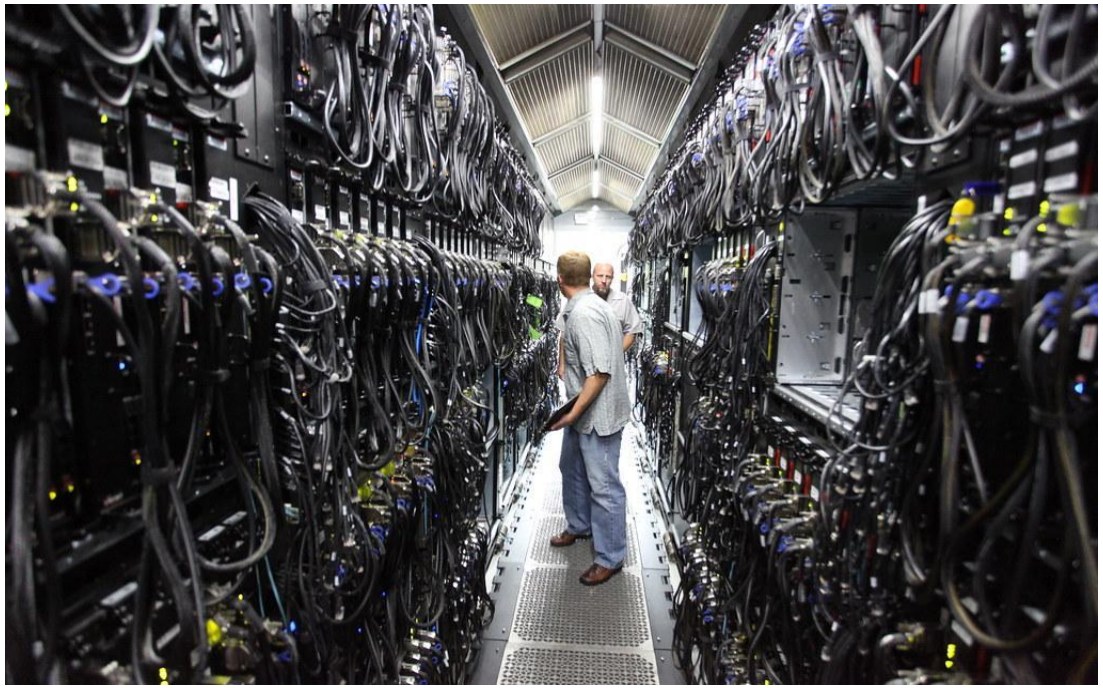


User devices

Source : C. Freitag et al., Patterns 2021

Information and Computing Technology (ICT)

Data Center and Networks

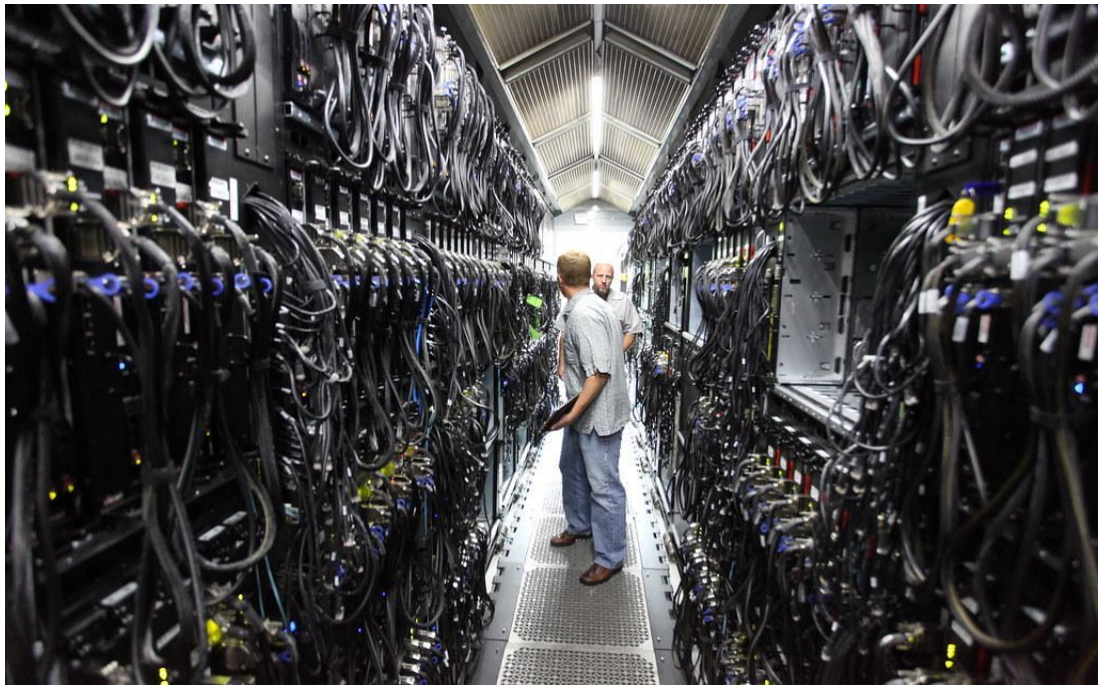


User devices

- ICT contributes to 3-4% of the total world carbon footprint (CFP) Source : C. Freitag et al., Patterns 2021

Information and Computing Technology (ICT)

Data Center and Networks



User devices

- ICT contributes to 3-4% of the total world carbon footprint (CFP) Source : C. Freitag et al., Patterns 2021
- Need for sector-wide regulations

Objectives of this work

Objectives of this work

Objective 1: Call to action** for the **industry** to include **detailed data in sustainability reports

Objectives of this work

Objective 1: Call to action** for the **industry** to include **detailed data in sustainability reports

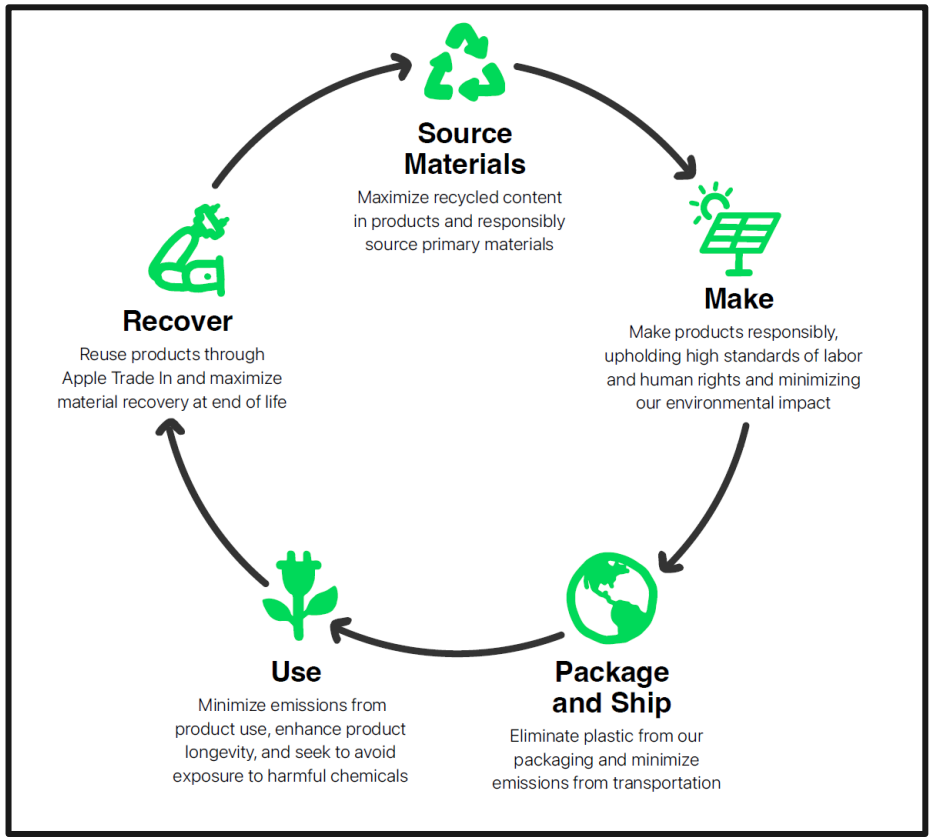
***Objective 2: Call to action** for the **community** to incorporate **sustainability-oriented** metrics for benchmarking chips and architectures*

Objectives of this work

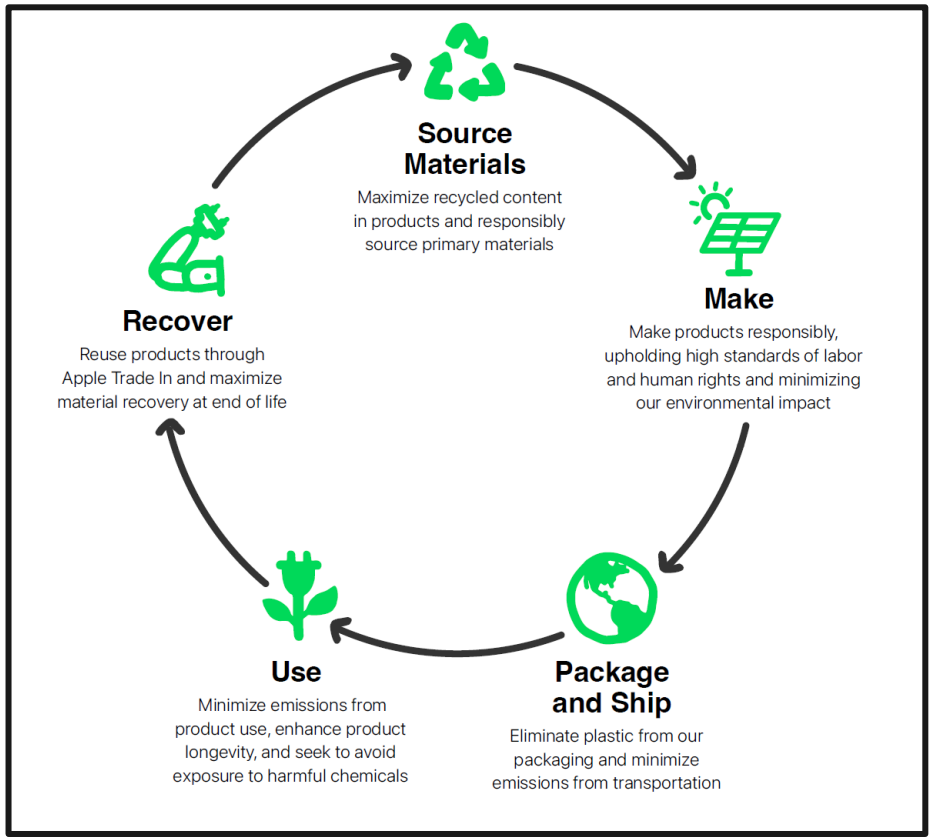
Objective 1: Call to action** for the **industry** to include **detailed data in sustainability reports

- **What are in corporate sustainability reports today?**
- What should sustainability reports include in the future?
- Importance of including detailed data in the report.

Sustainability reports today



Sustainability reports today



Greenhouse gas emissions	iPhone 15 Pro 128GB	iPhone 15 Pro Max 256GB
Total product footprint	66 kg CO_2e	75 kg CO_2e
Apple emissions from utility-purchased electricity (scope 2)	0 kg CO_2e	0 kg CO_2e
Life cycle product emissions (scope 3)	66 kg CO_2e	75 kg CO_2e
• Production	83%	83%
• Transportation	3%	3%
• Product use	15%	15%
• End-of-life processing	<1%	<1%
GHG reductions achieved[9]	↓29%	↓30%

Note: Percentages may not total 100 due to rounding.

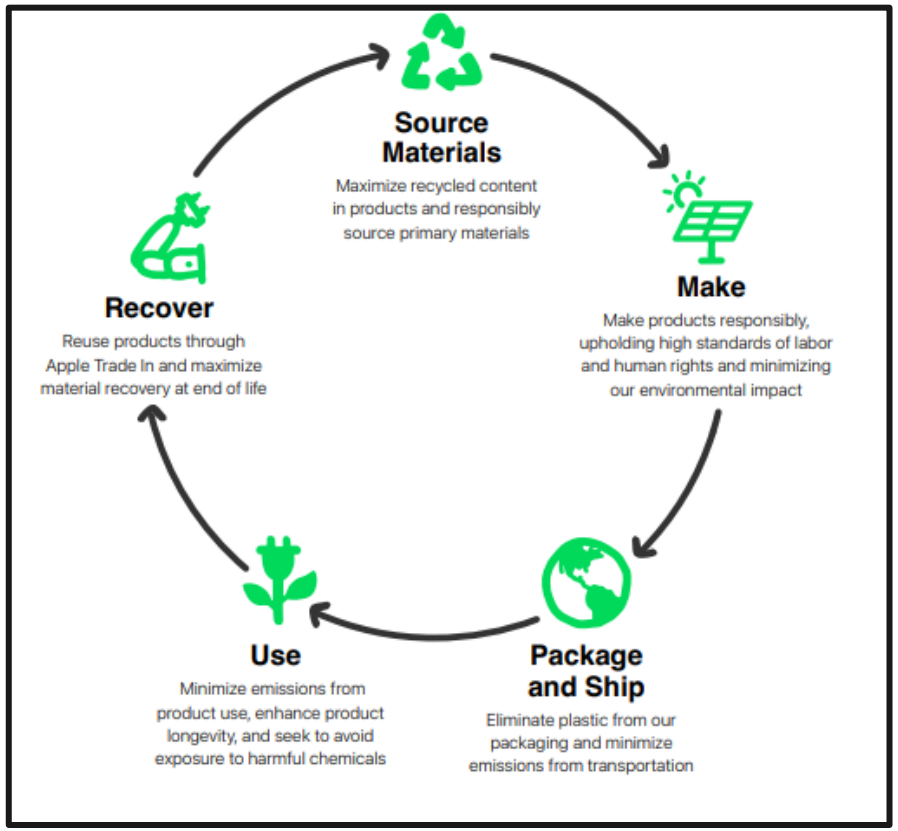
Source : Apple sustainability reports

Objectives of this work

Objective 1: Call to action** for the **industry** to include **detailed data in sustainability reports

- What are in corporate sustainability reports today?
- **What should sustainability reports include in the future?**
- Importance of including detailed data in the report.

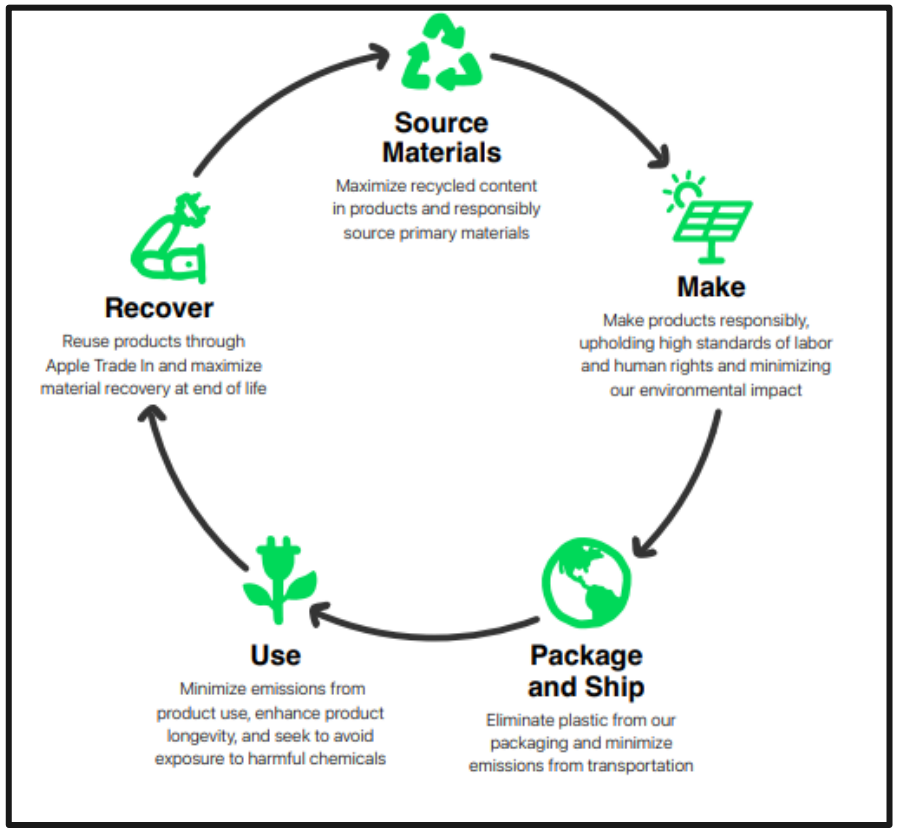
Ideal sustainability reports of tomorrow



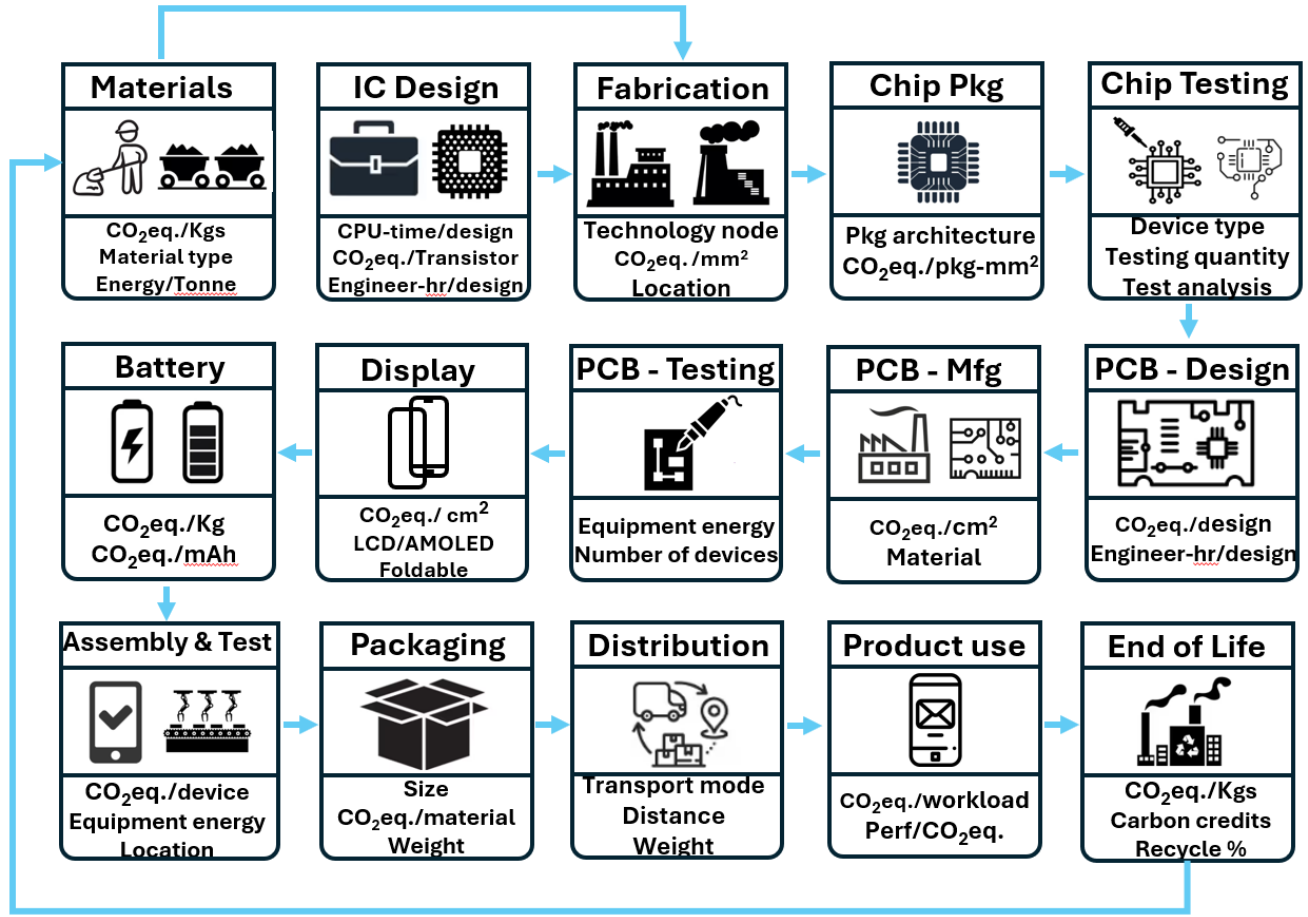
Source : Apple sustainability reports

Ideal sustainability reports of tomorrow

Detailed lifecycle analysis of a product

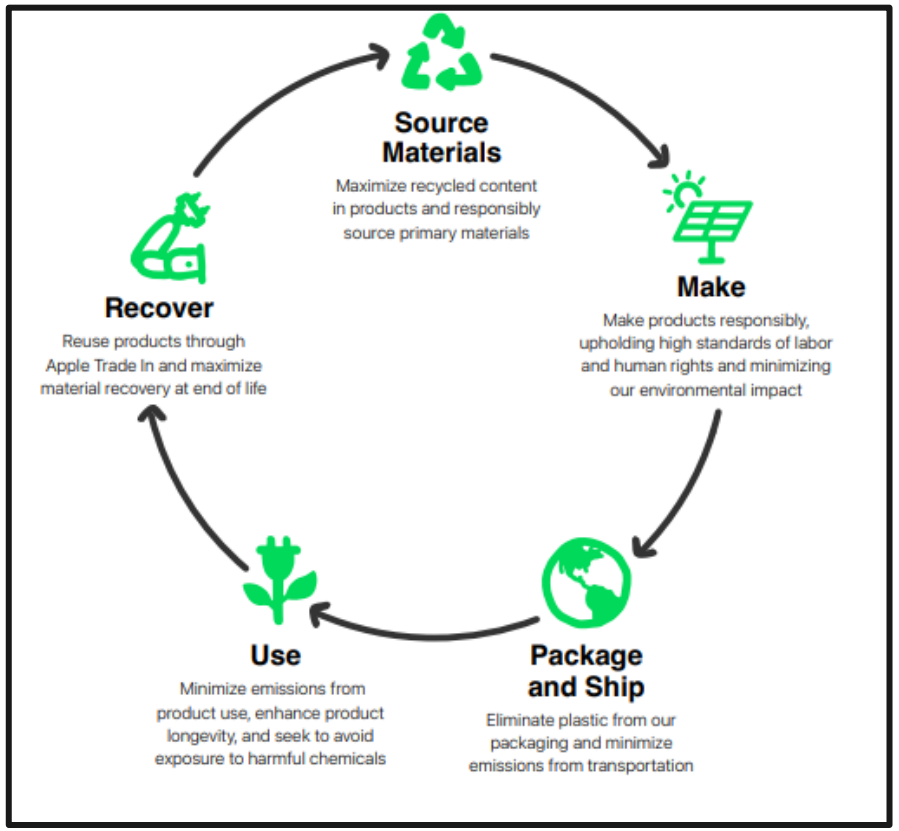


Source : Apple sustainability reports

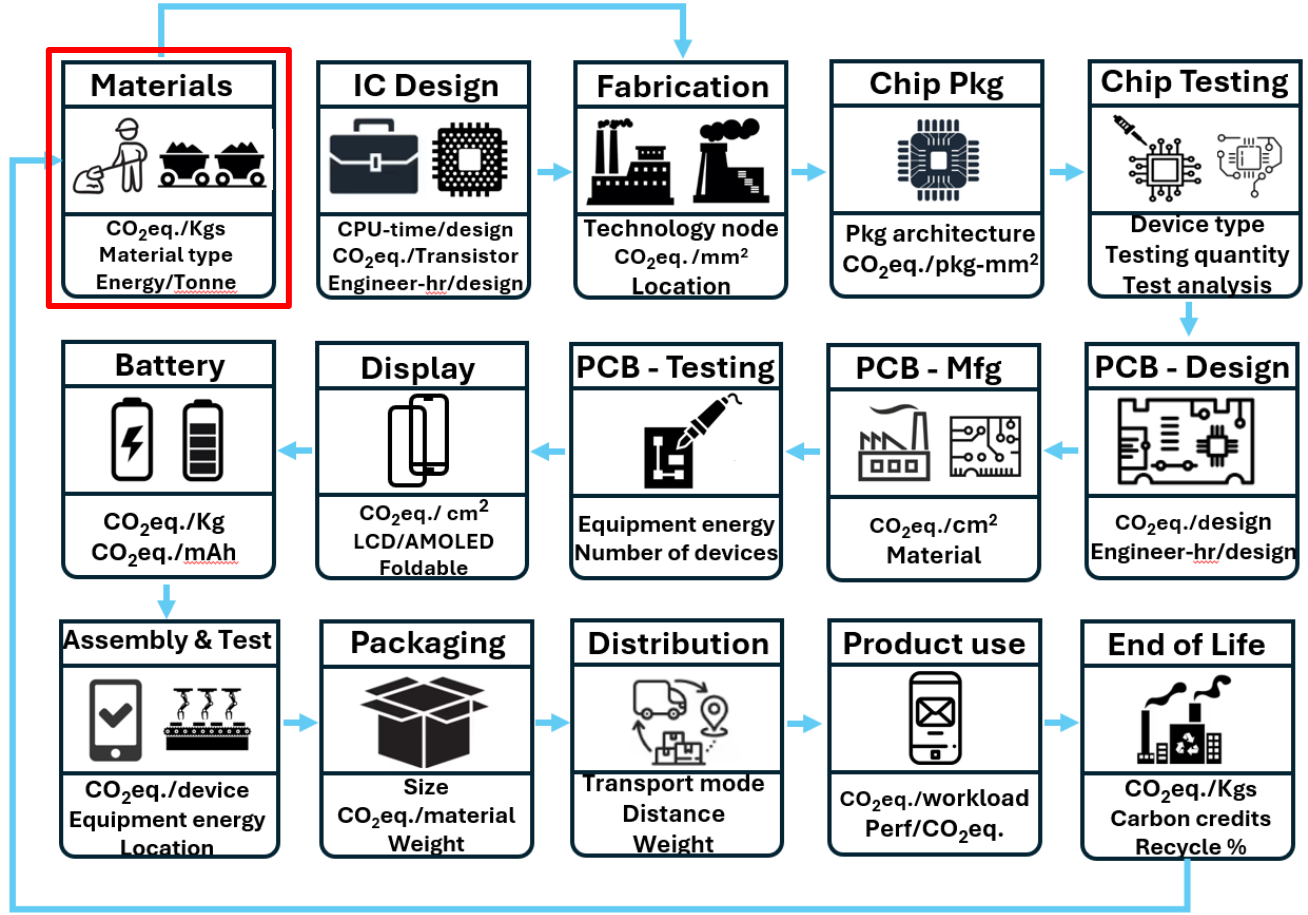


Ideal sustainability reports of tomorrow

Detailed lifecycle analysis of a product

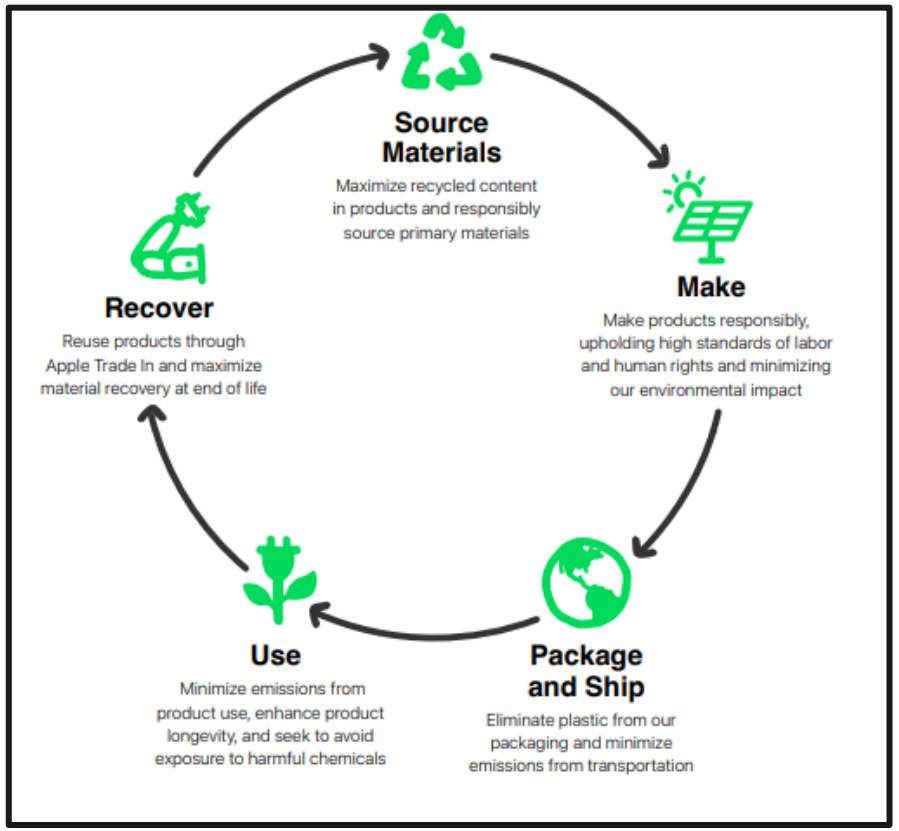


Source : Apple sustainability reports

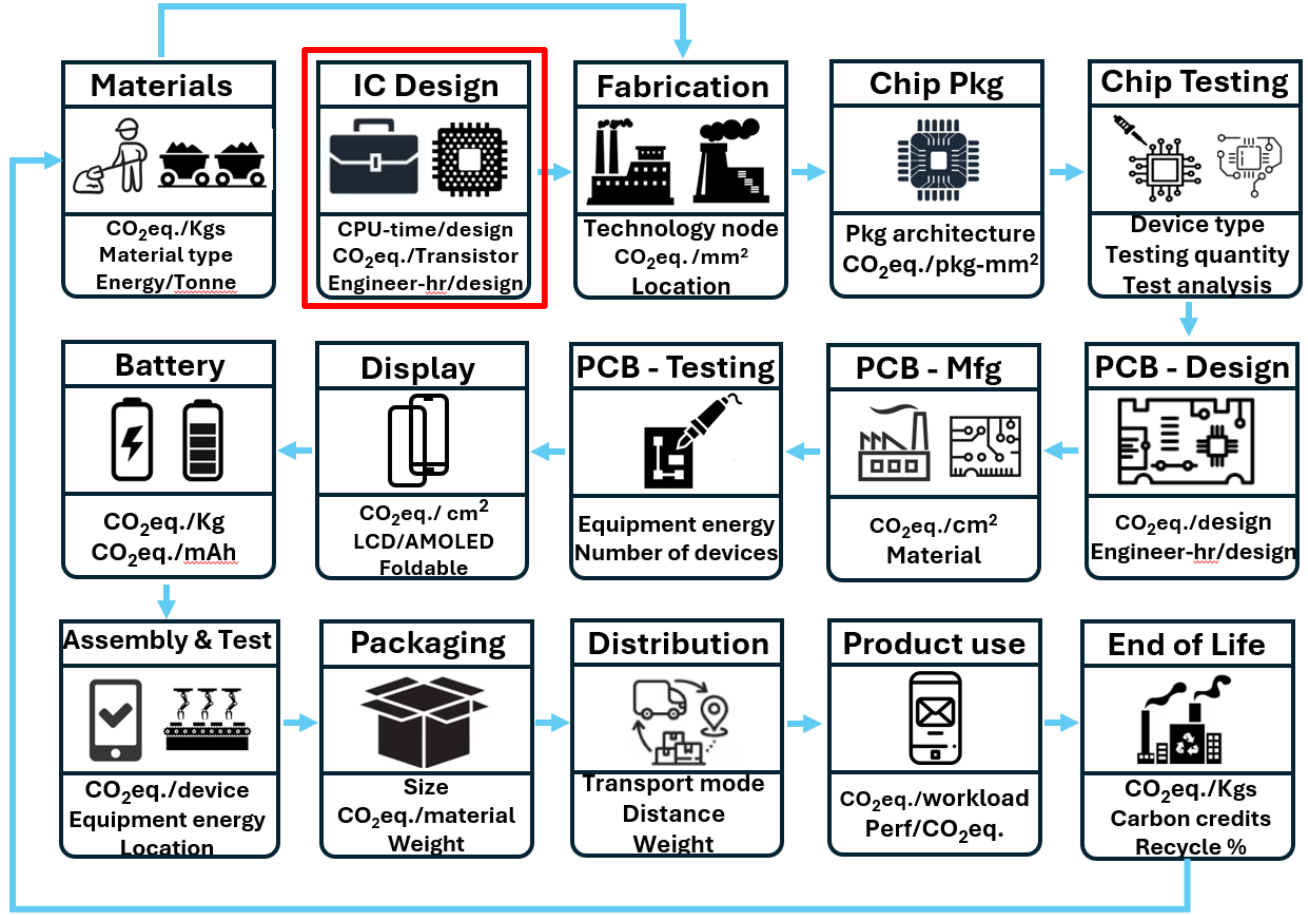


Ideal sustainability reports of tomorrow

Detailed lifecycle analysis of a product

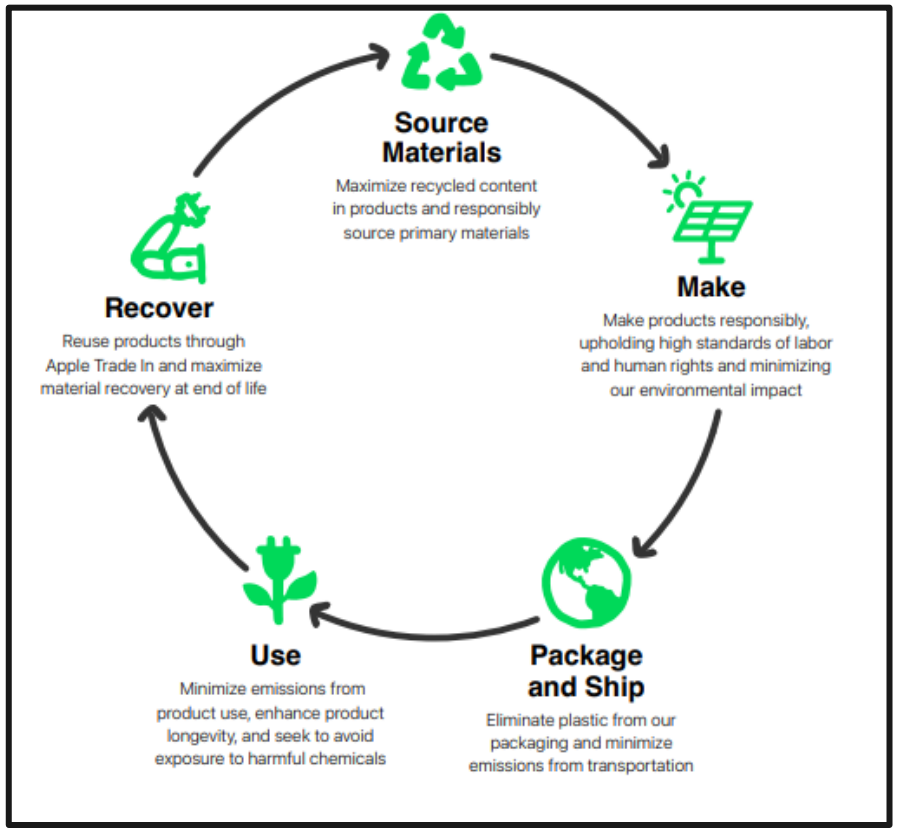


Source : Apple sustainability reports

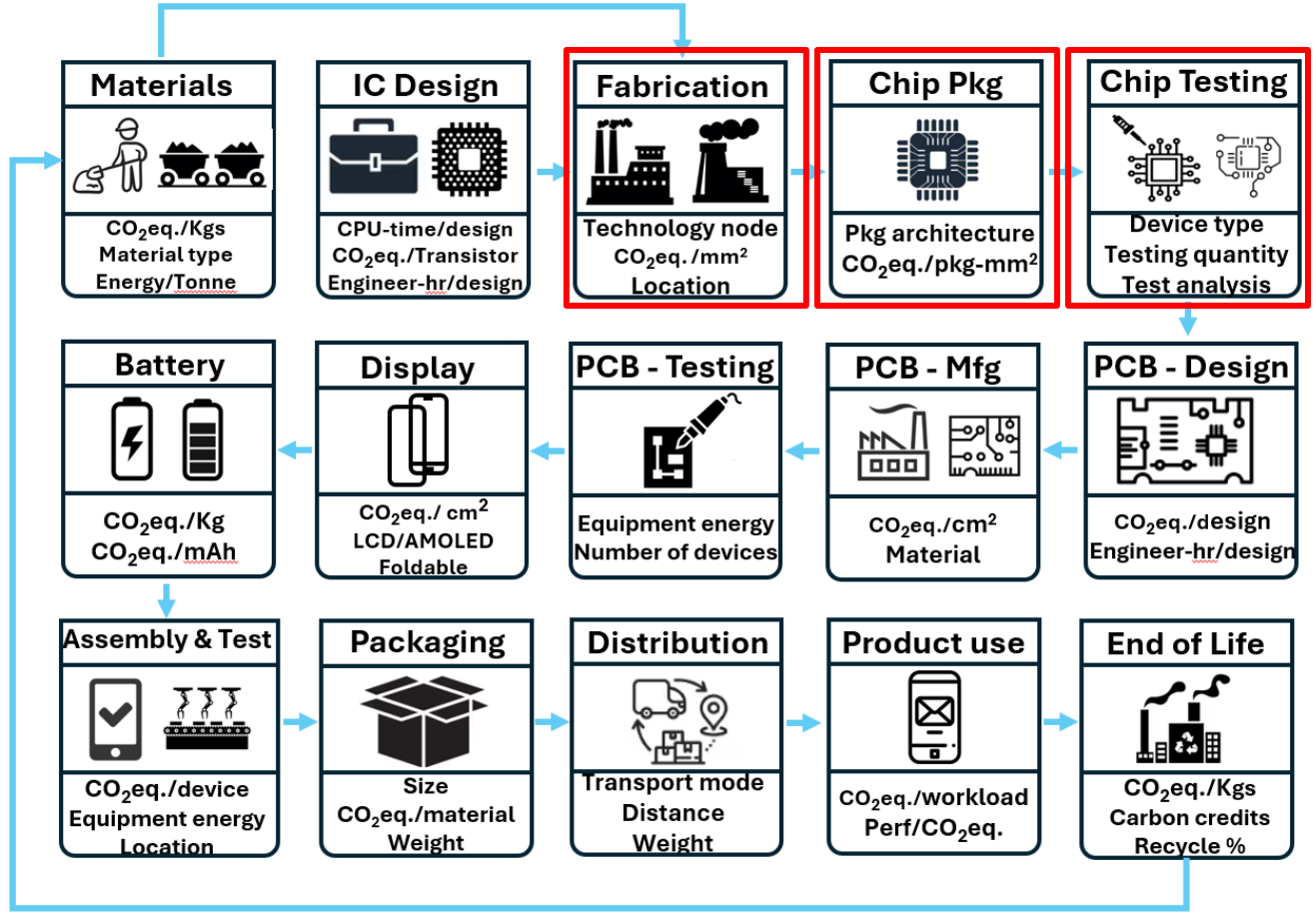


Ideal sustainability reports of tomorrow

Detailed lifecycle analysis of a product

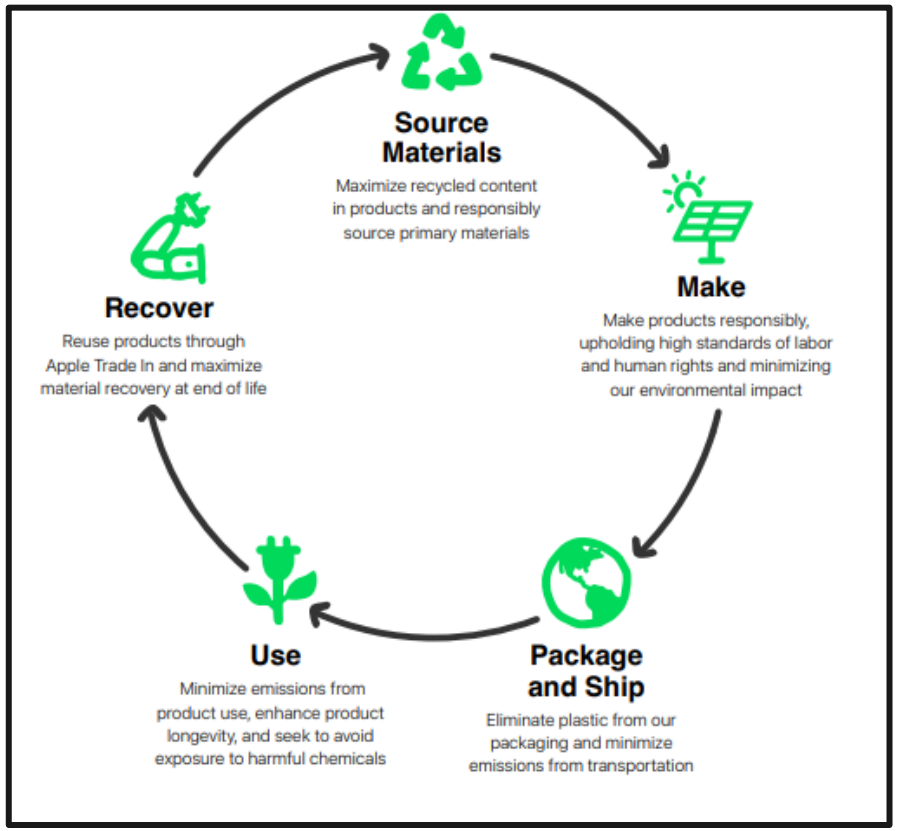


Source : Apple sustainability reports

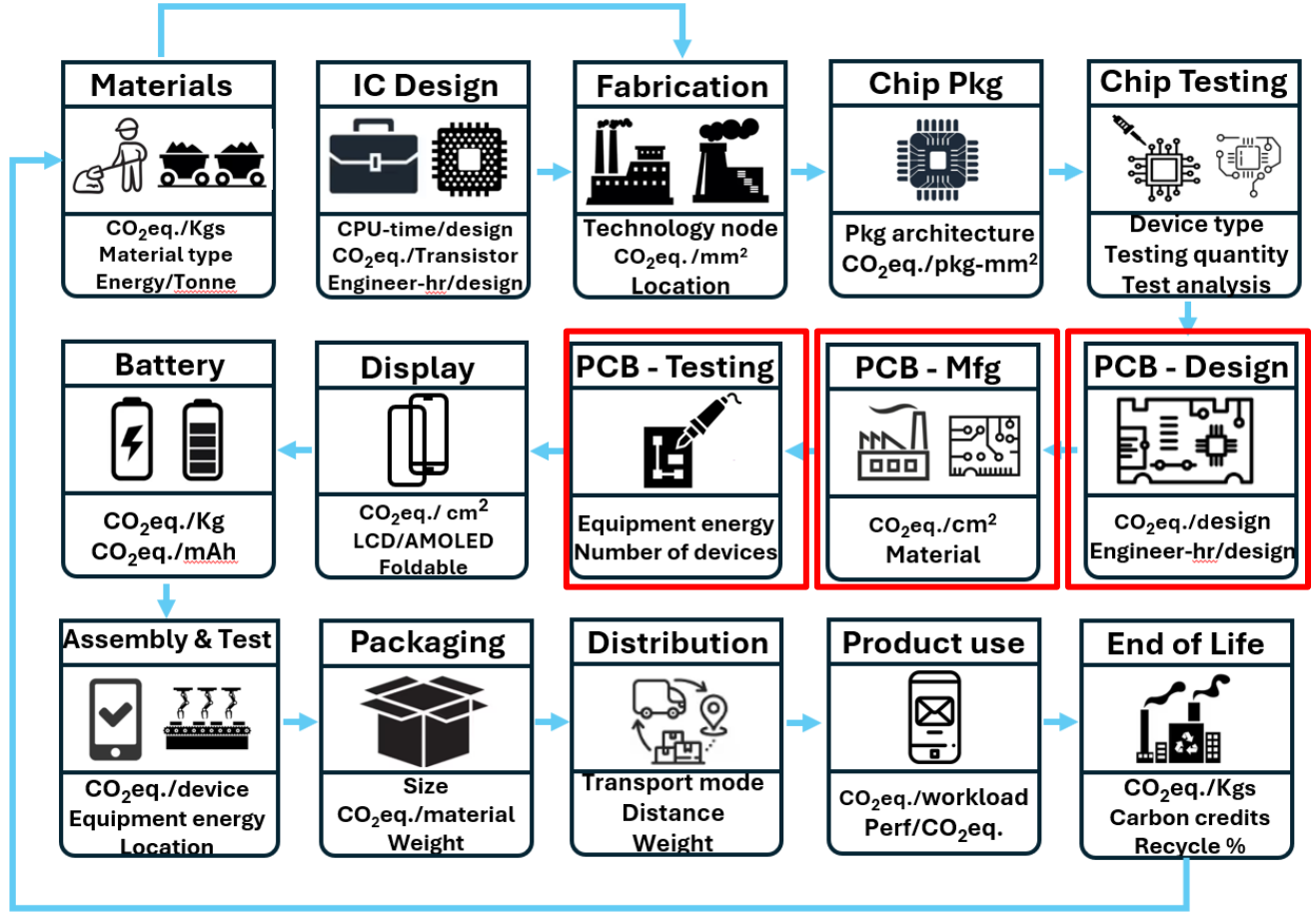


Ideal sustainability reports of tomorrow

Detailed lifecycle analysis of a product

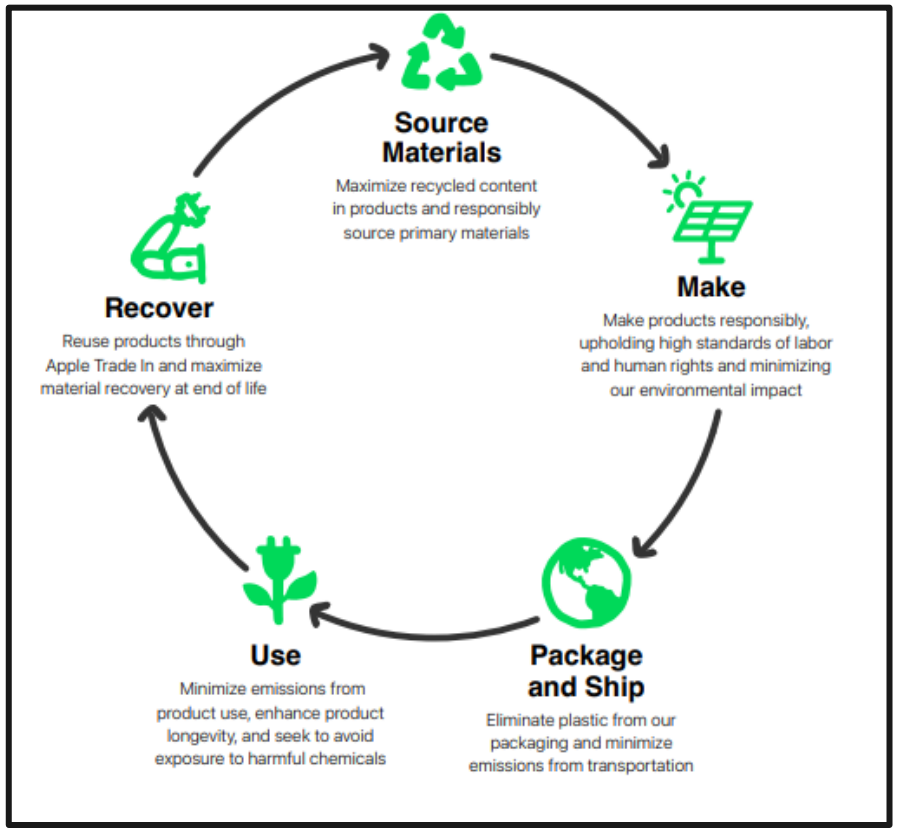


Source : Apple sustainability reports

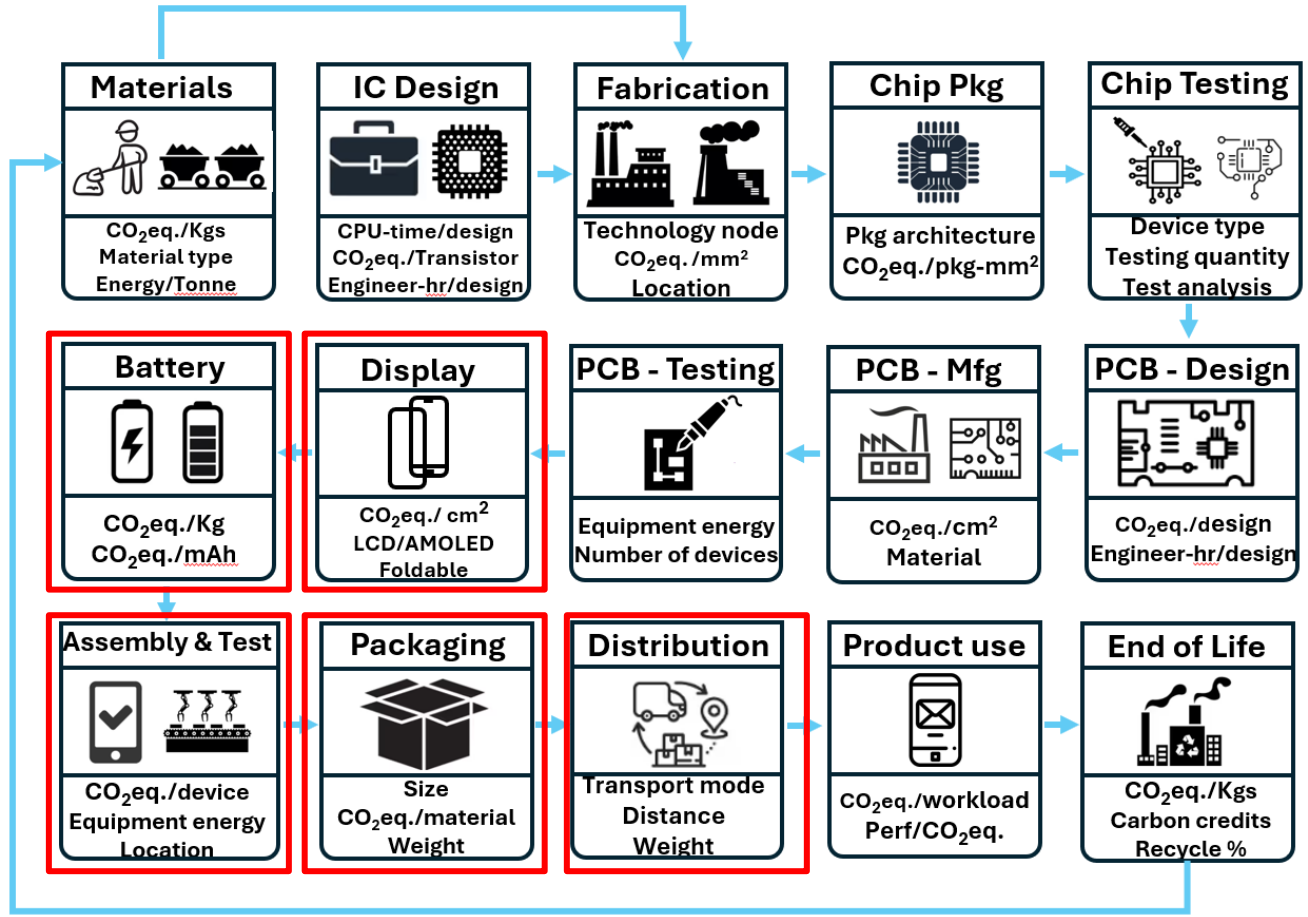


Ideal sustainability reports of tomorrow

Detailed lifecycle analysis of a product

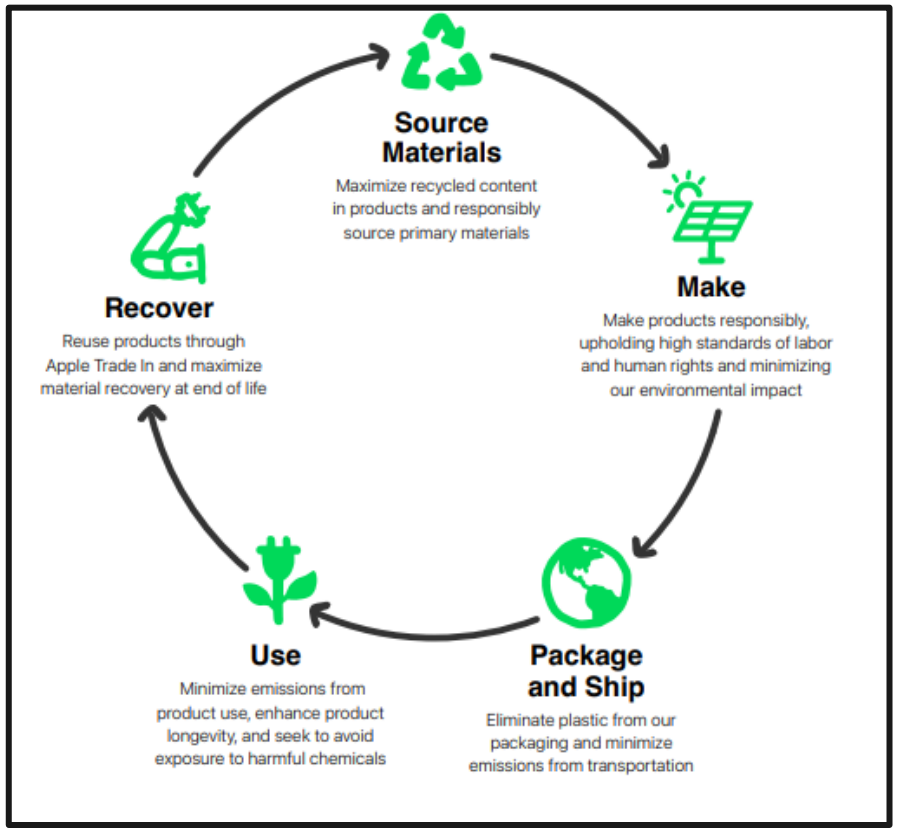


Source : Apple sustainability reports

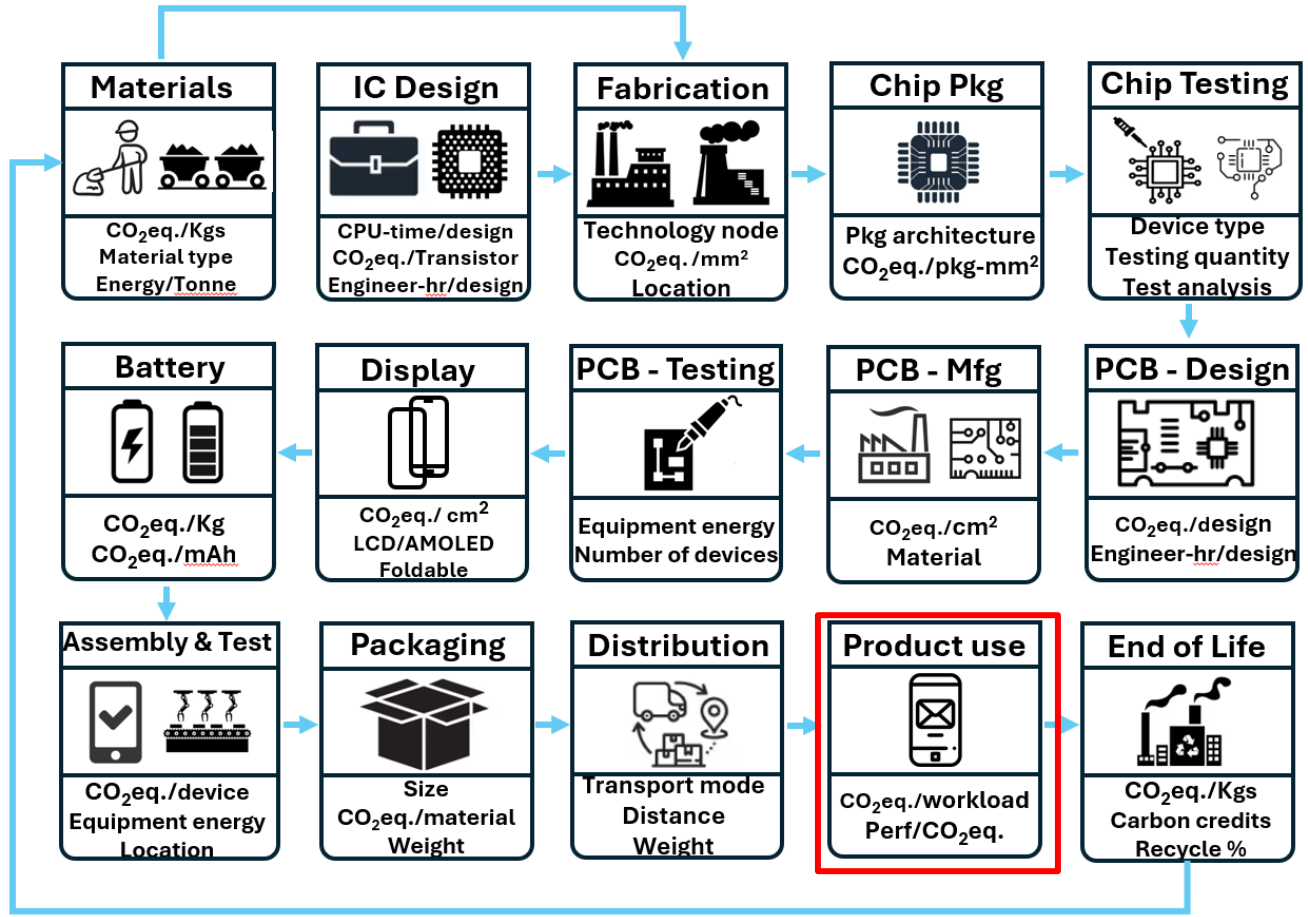


Ideal sustainability reports of tomorrow

Detailed lifecycle analysis of a product

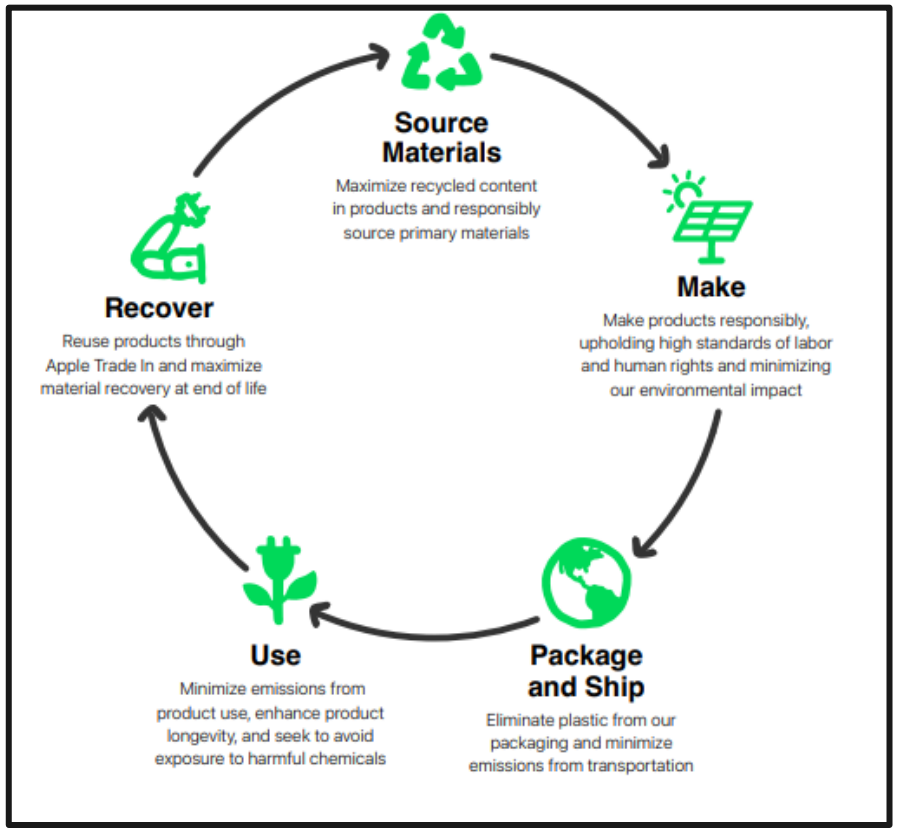


Source : Apple sustainability reports

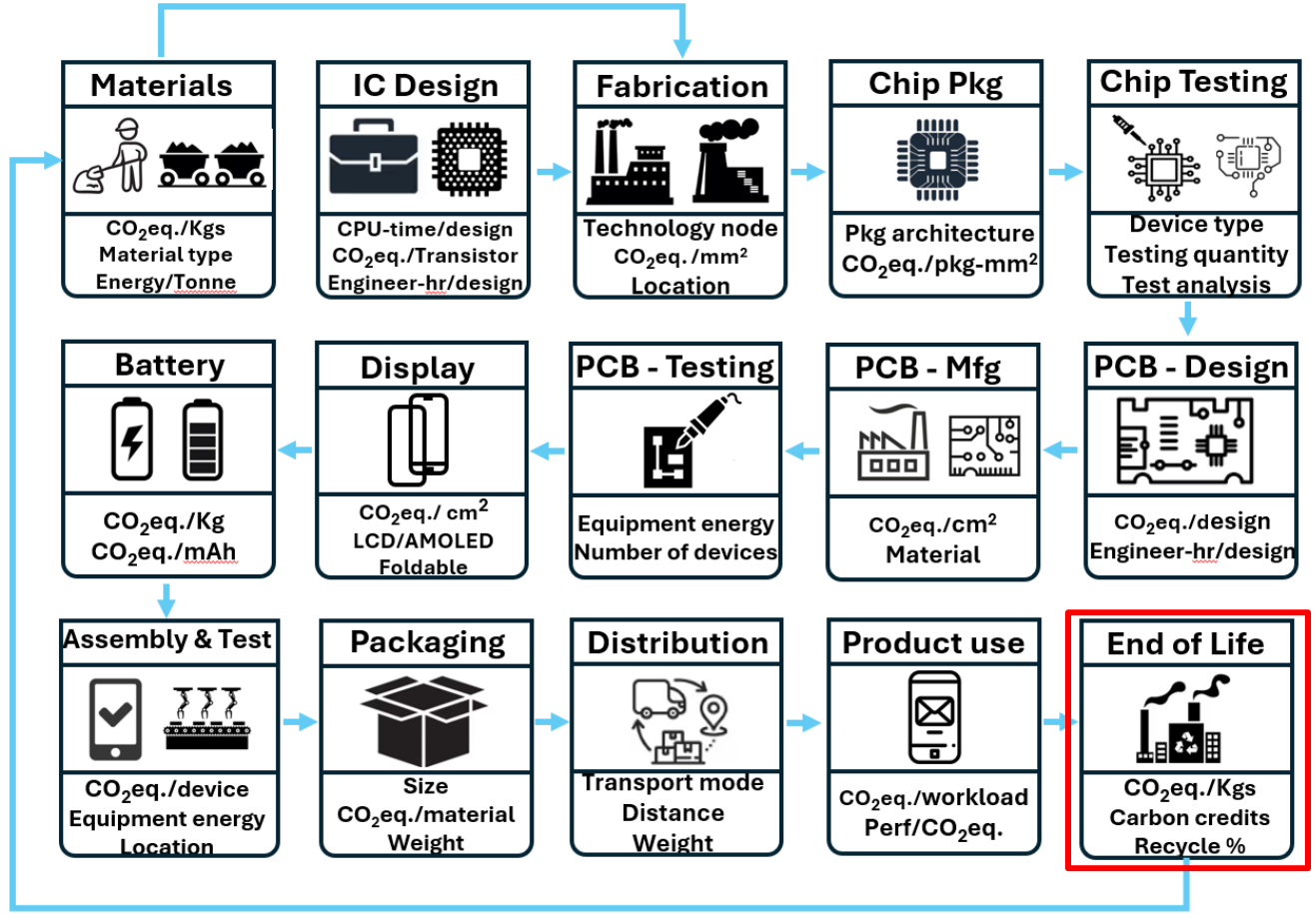


Ideal sustainability reports of tomorrow

Detailed lifecycle analysis of a product



Source : Apple sustainability reports



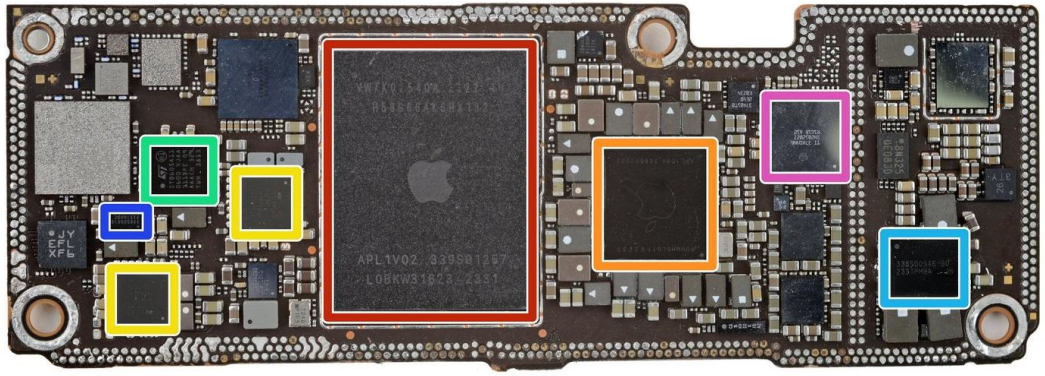
Ideal sustainability reports of tomorrow

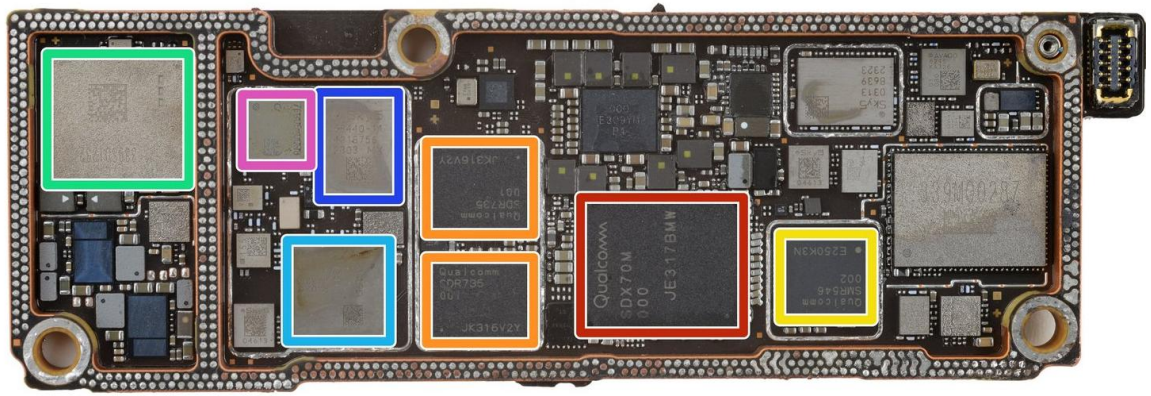
Today's report

Ideal sustainability reports of tomorrow

Today's report

Future report





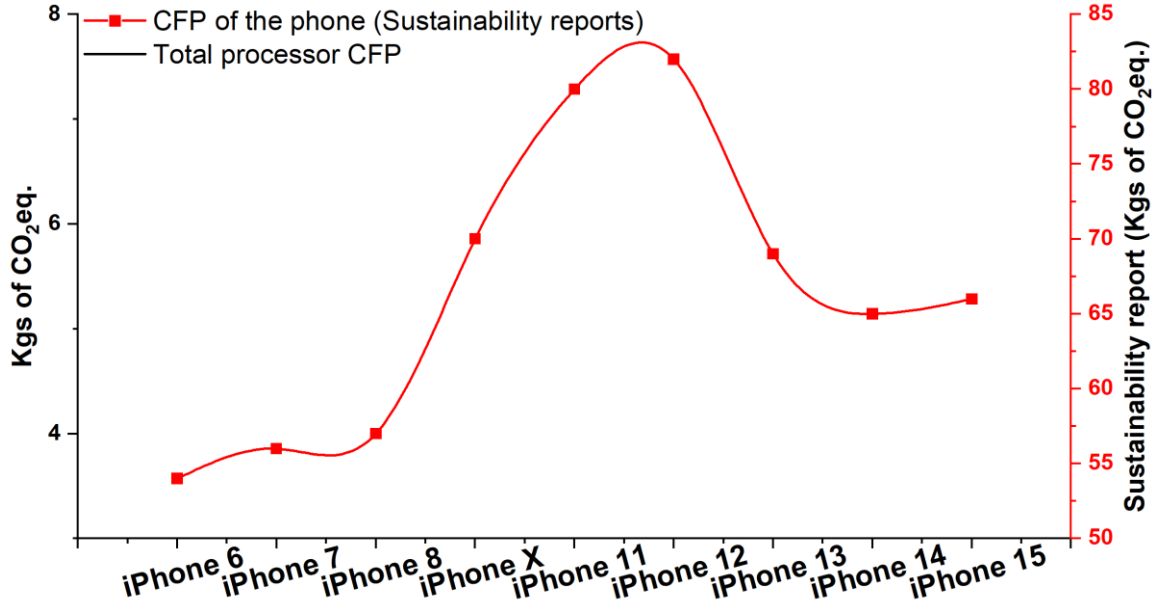
Source : ifixit

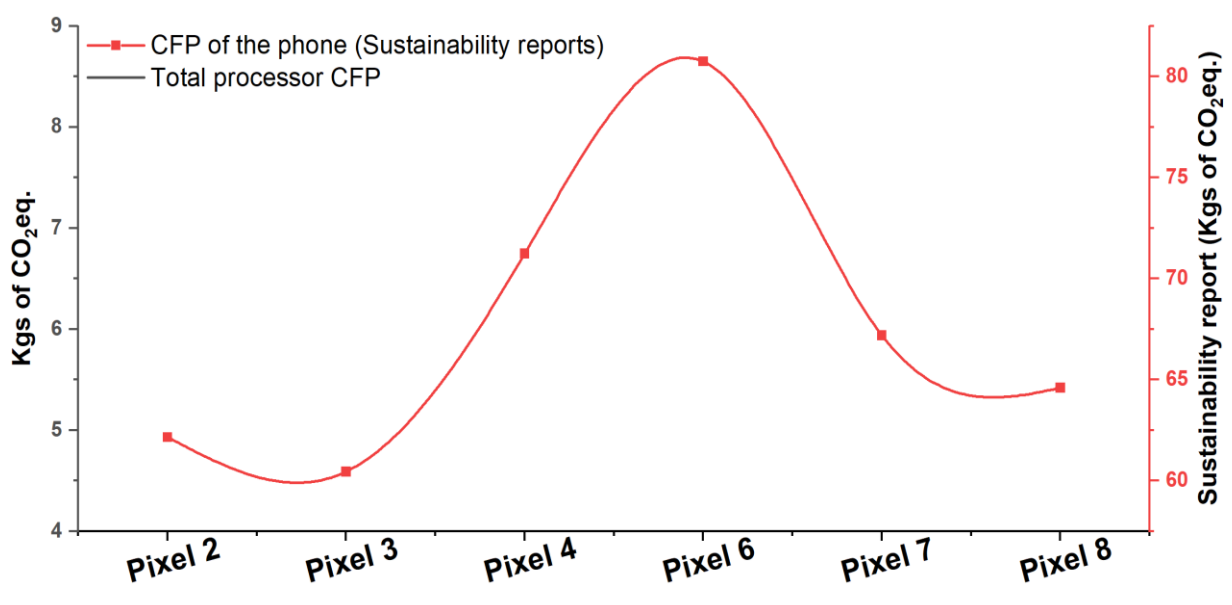
Objectives of this work

Objective 1: Call to action** for the **industry** to include **detailed data in sustainability reports

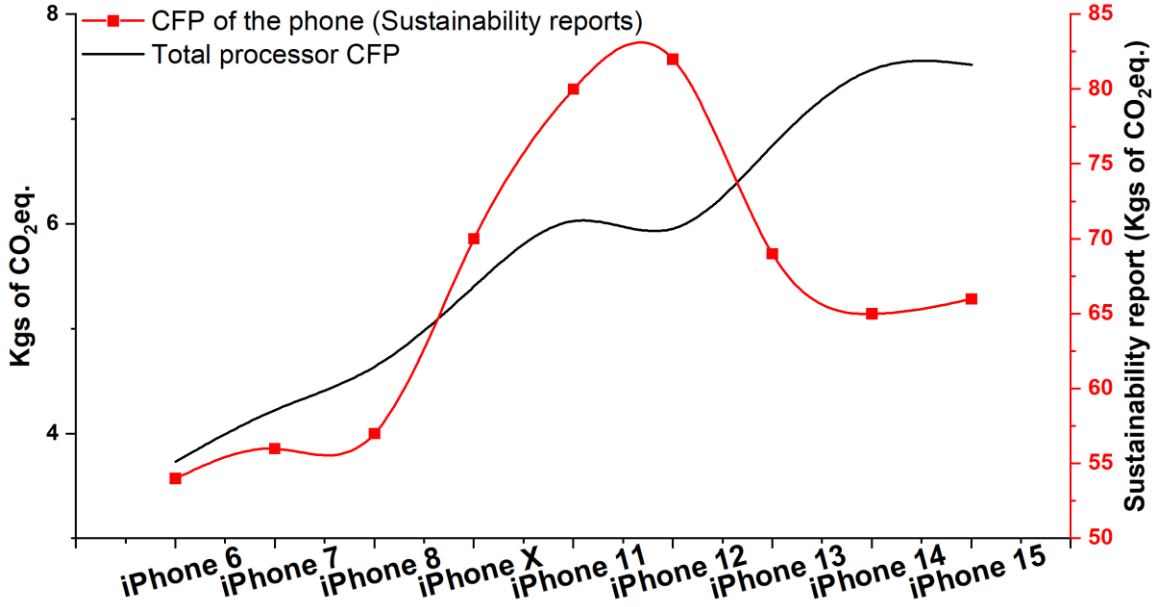
- What are in corporate sustainability reports today?
- What should sustainability reports include in the future?
- **Importance of including detailed data in the report.**

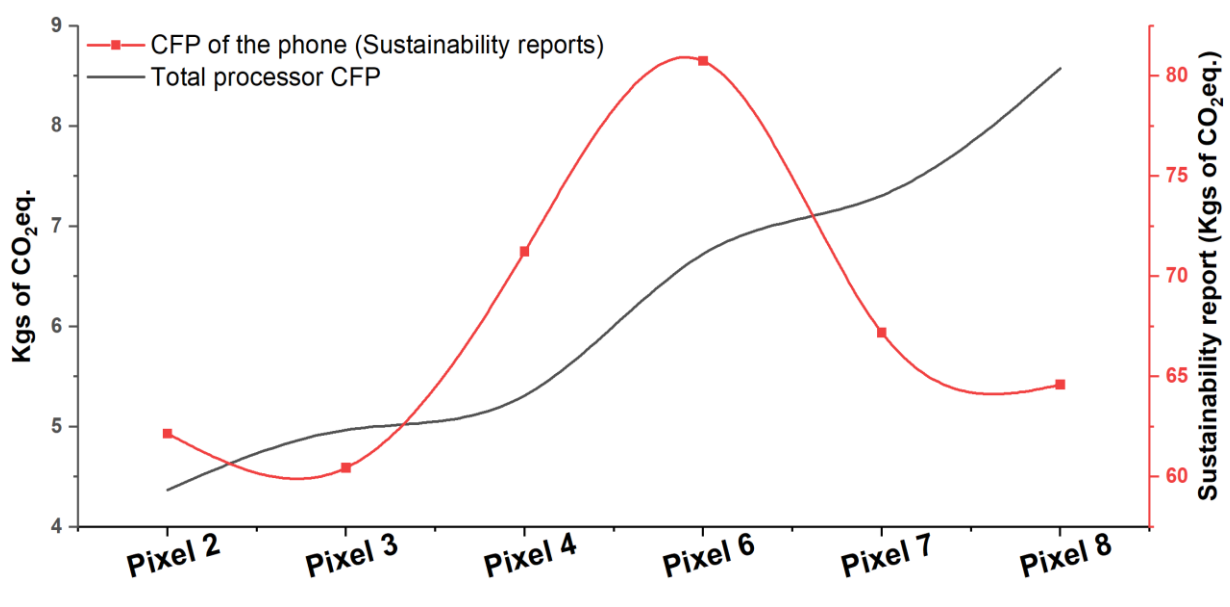
Importance of the detailed data – Discrepancies in CFP





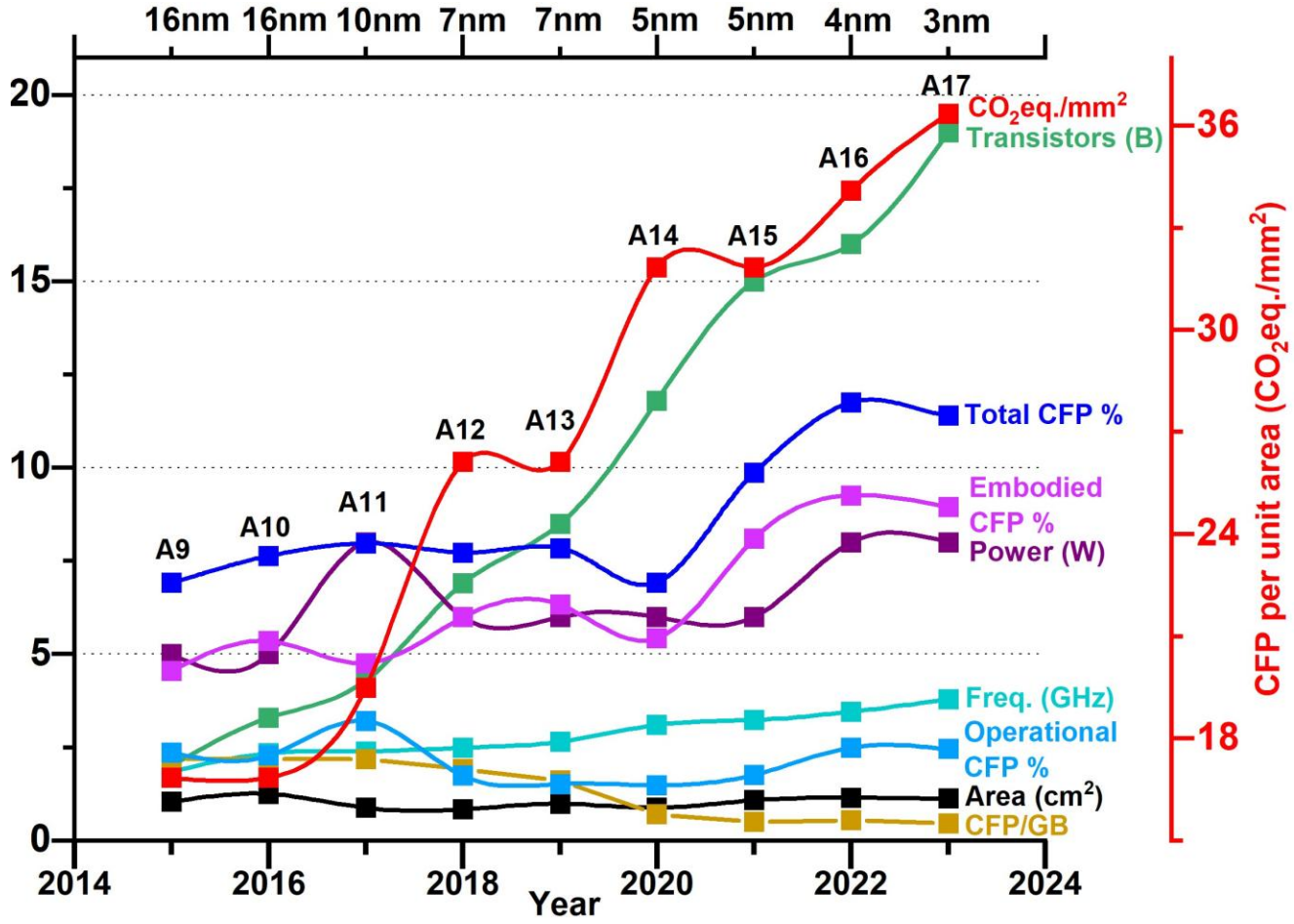
Importance of the detailed data – Discrepancies in CFP





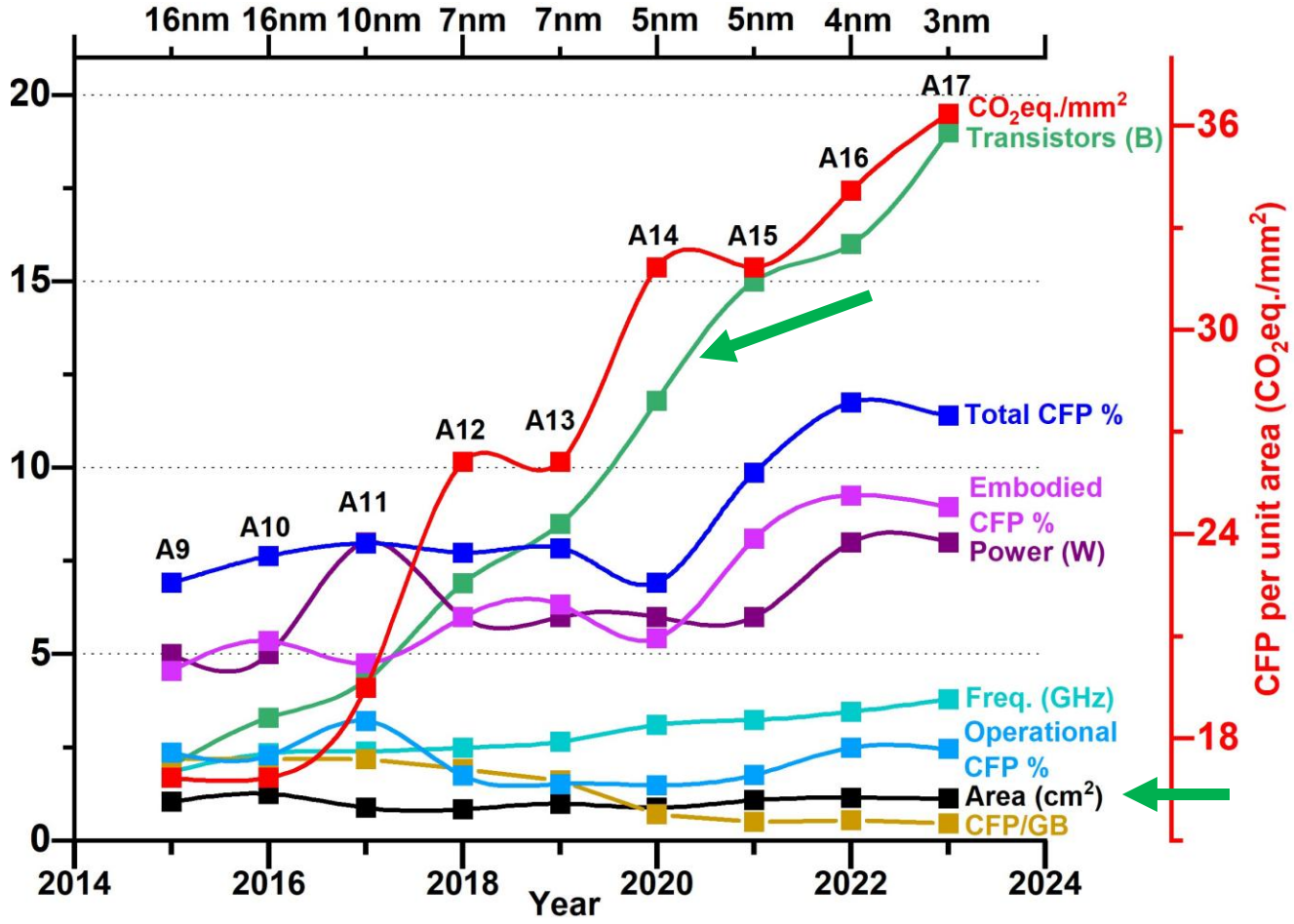
- Phone CFP trend over the years from sustainability reports
- Processor CFP increasing
- Need for more granular sustainable metrics in the reports

Importance of the detailed data



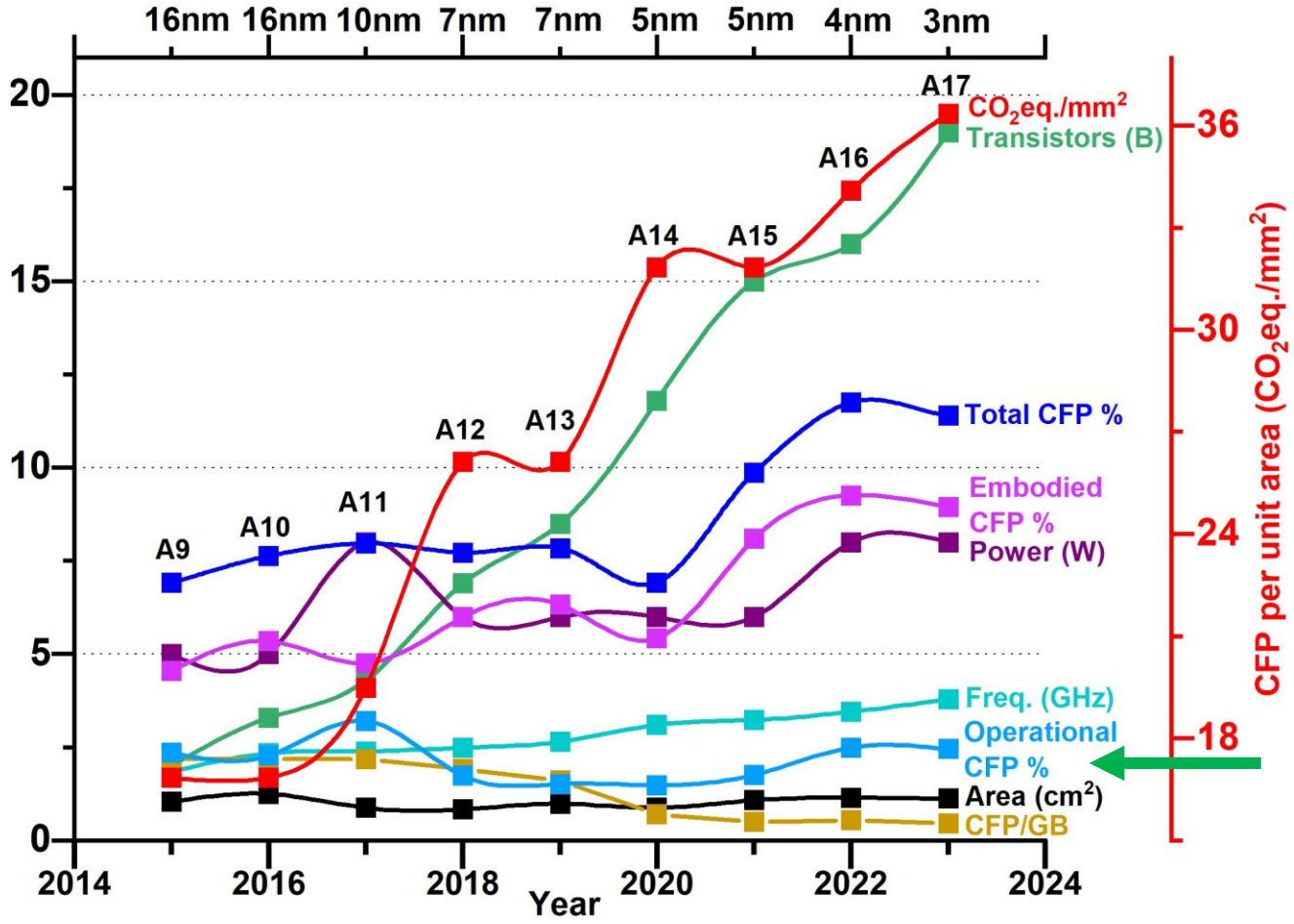
Data collected using ACT (Gupta et.al), ECO-CHIP (Sudarshan et.al)

Importance of the detailed data



Data collected using ACT (Gupta et.al), ECO-CHIP (Sudarshan et.al)

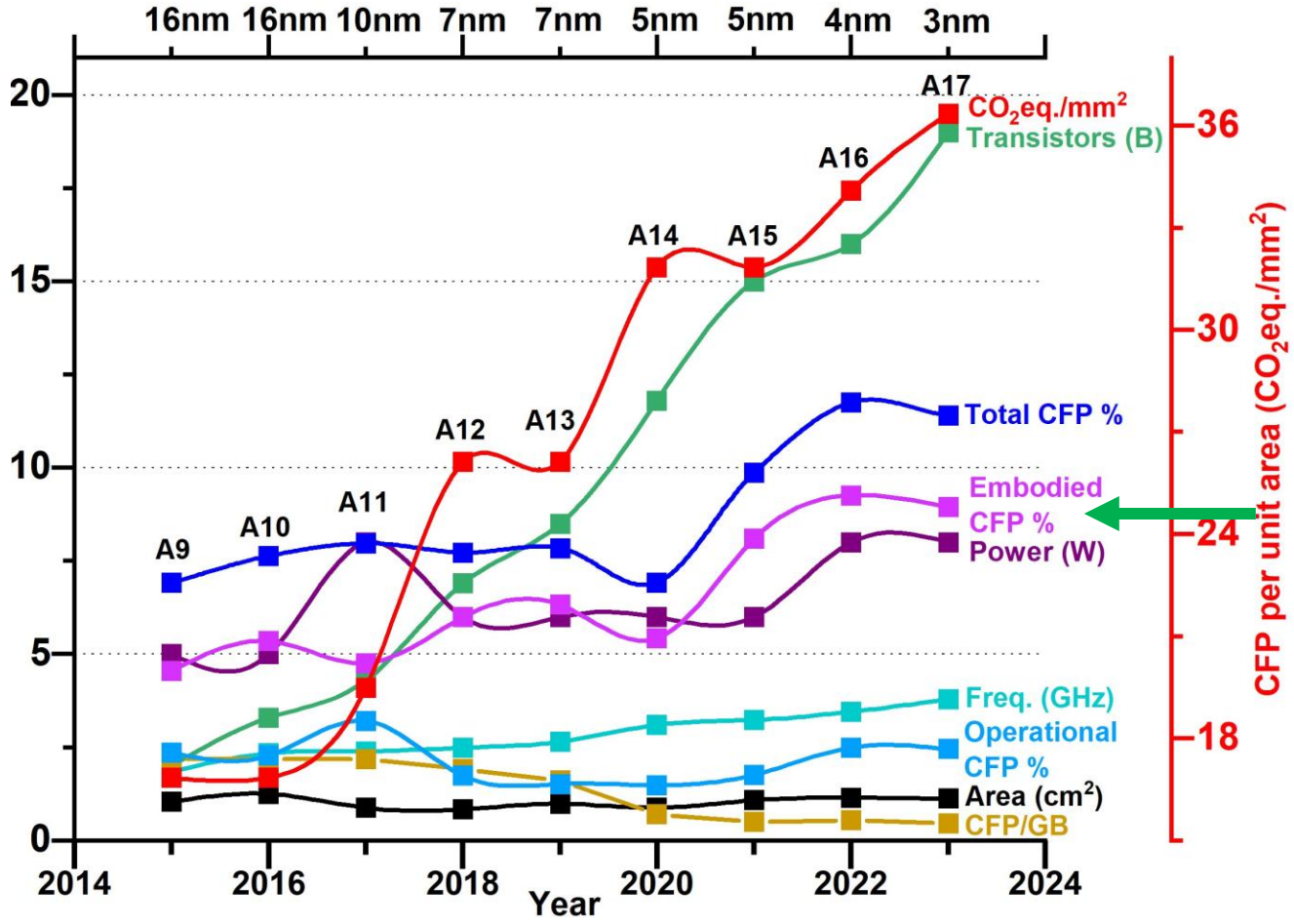
Importance of the detailed data



Data collected using ACT (Gupta et.al), ECO-CHIP (Sudarshan et.al)

- "Operational CFP %" has remained almost constant over the years

Importance of the detailed data



Data collected using ACT (Gupta et.al), ECO-CHIP (Sudarshan et.al)

- "Operational CFP %" has remained almost constant over the years
- "Embodied CFP %" has increased over the years

Objectives of this work

***Objective 2: Call to action** for the **community** to incorporate **sustainability-oriented** metrics for benchmarking chips and architectures*

- Traditional metrics in the chip design
- Proposed metrics for benchmarking chip design and processors for sustainability

Processor benchmarking metrics

Traditional Metrics

- **Processor**
  - Power, performance, area
  - Latency bandwidth
  - Cost
  - Performance per Watt
  - Throughput
  - Process node

Processor benchmarking metrics

Traditional Metrics

- **Processor**
  - Power, performance, area
  - Latency bandwidth
  - Cost
  - Performance per Watt
  - Throughput
  - Process node
- **Memory**
  - Refresh rate
  - Area
  - Density

Processor benchmarking metrics

Traditional Metrics

- **Processor**
  - Power, performance, area
  - Latency bandwidth
  - Cost
  - Performance per Watt
  - Throughput
  - Process node
- **Memory**
  - Refresh rate
  - Area
  - Density

Sustainability Metrics

- Performance Sustainability Index (Perf-SI)

Processor benchmarking metrics

Traditional Metrics

- **Processor**
  - Power, performance, area
  - Latency bandwidth
  - Cost
  - Performance per Watt
  - Throughput
  - Process node
- **Memory**
  - Refresh rate
  - Area
  - Density

Sustainability Metrics

- Performance Sustainability Index (Perf-SI)
- Workload-dependent carbon footprint

Processor benchmarking metrics

Traditional Metrics

- **Processor**
  - Power, performance, area
  - Latency bandwidth
  - Cost
  - Performance per Watt
  - Throughput
  - Process node
- **Memory**
  - Refresh rate
  - Area
  - Density

Sustainability Metrics

- Performance Sustainability Index (Perf-SI)
- Workload-dependent carbon footprint
- Carbon per billion transistors

Processor benchmarking metrics

Traditional Metrics

- **Processor**
  - Power, performance, area
  - Latency bandwidth
  - Cost
  - Performance per Watt
  - Throughput
  - Process node
- **Memory**
  - Refresh rate
  - Area
  - Density

Sustainability Metrics

- Performance Sustainability Index (Perf-SI)
- Workload-dependent carbon footprint
- Carbon per billion transistors
- Mobile SSD:
  - CFP/GB
  - Memory CFP per unit area

Performance Sustainability Index- Performance per CO_2eq.

$$Perf - SI = \frac{Performance}{Total\ CO_2eq.}$$

Performance Sustainability Index- Performance per $CO_2eq.$

$$Perf - SI = \frac{Performance}{Total\ CO_2eq.}$$

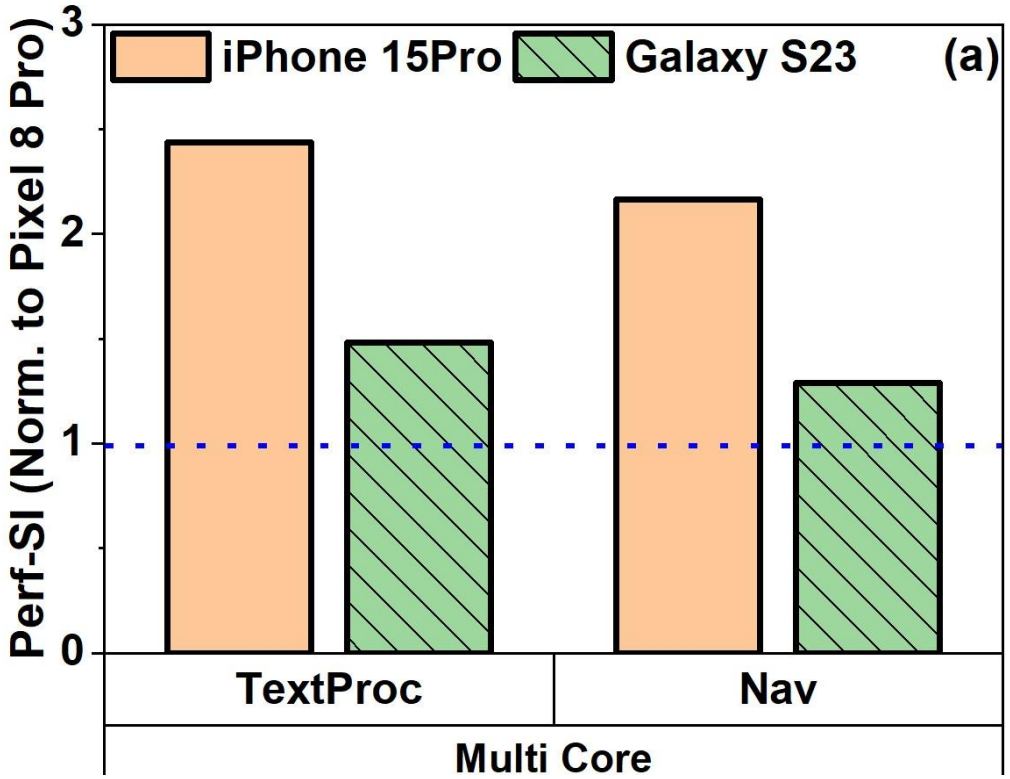
- **Embodied CFP**
- **Operational CFP**

- The total CFP considers contributions of both embodied and operational CFP
- CFP and performance have a relation with each other, and this metric can help make sustainable design decisions

Performance Sustainability Index- Performance per $CO_2eq.$

$$Perf - SI = \frac{Performance}{Total\ CO_2eq.}$$

- Embodied CFP
- Operational CFP



- The total CFP considers contributions of both embodied and operational CFP
- CFP and performance have a relation with each other, and this metric can help make sustainable design decisions
- Perf-SI considers the device's area, power, and sustainably impact along with performance for comprehensive evaluation.

Workload-dependent carbon footprint

$$C_{workload} = T_{workload} \times P \times CI$$

Workload-dependent carbon footprint

$$C_{workload} = T_{workload} \times P \times CI$$

- $T_{workload}$: Time taken to run the workload
- CI: Carbon intensity (Kgs of CO_2 eq. per kWh)
- P: Processor power

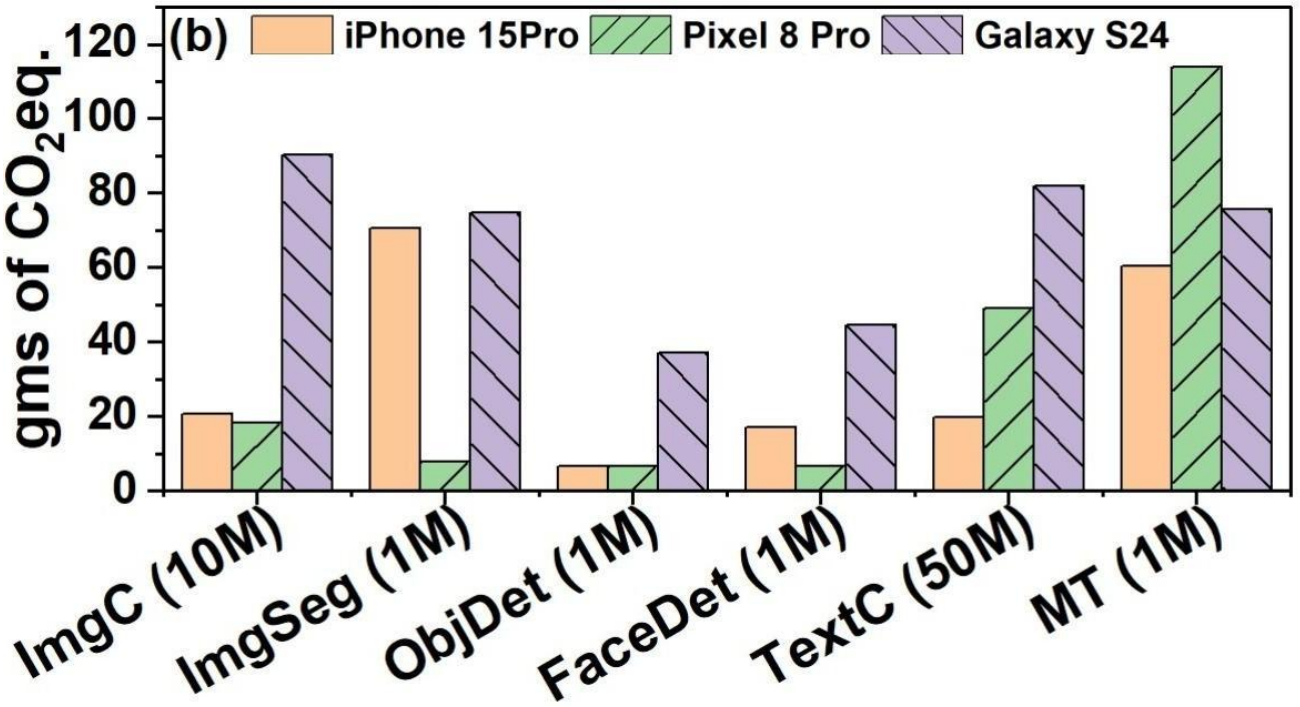
Workload-dependent carbon footprint

$$C_{workload} = T_{workload} \times P \times CI$$

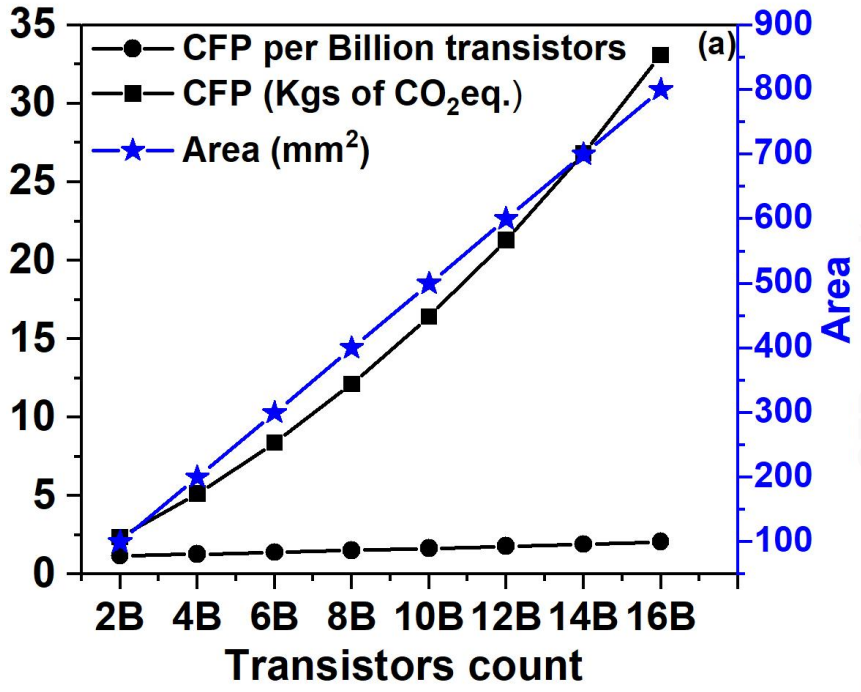
- $T_{workload}$: Time taken to run the workload
- CI: Carbon intensity (Kgs of CO_2 eq. per kWh)
- P: Processor power

- Consider workload targeting
  - ML applications
  - GPU
  - CPU

- Useful for comparing devices based on workload

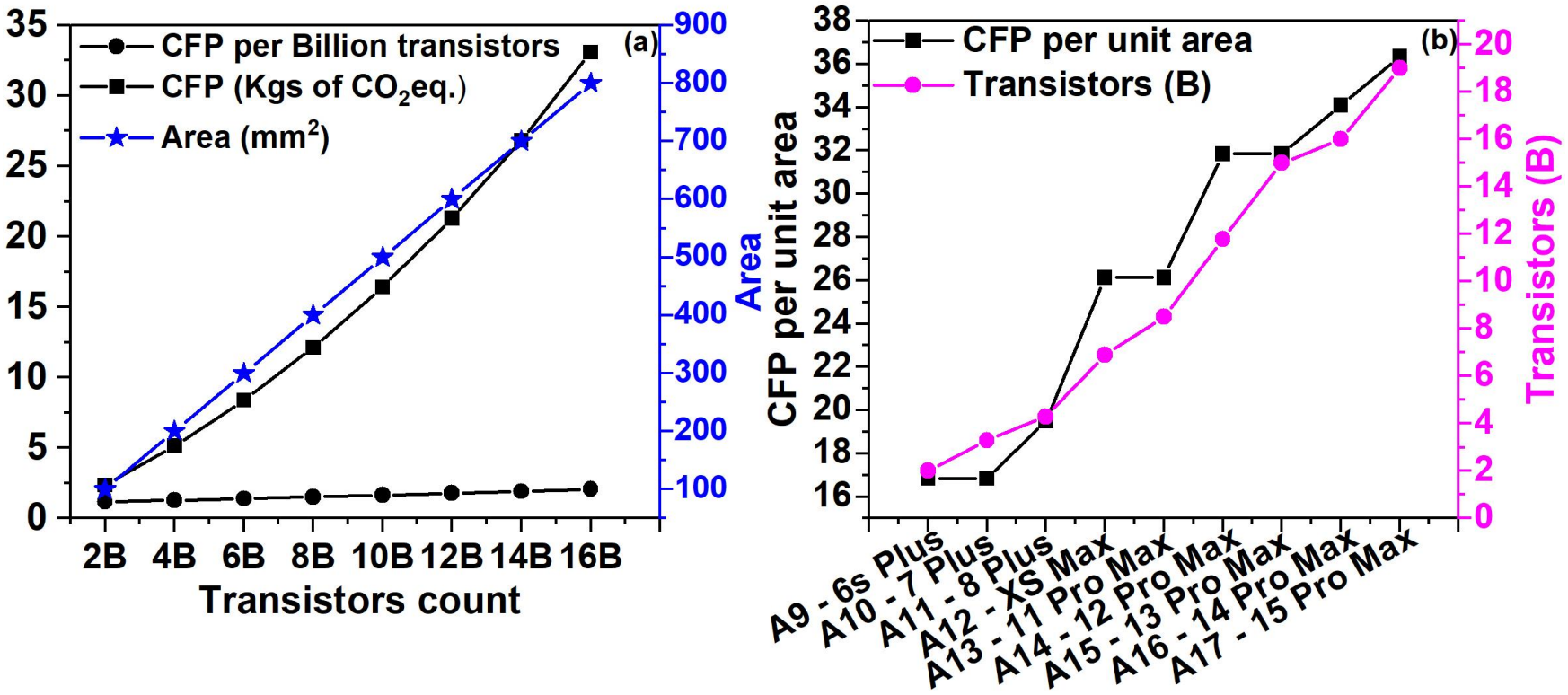


Transistors CFP contribution – CFP per billion transistor



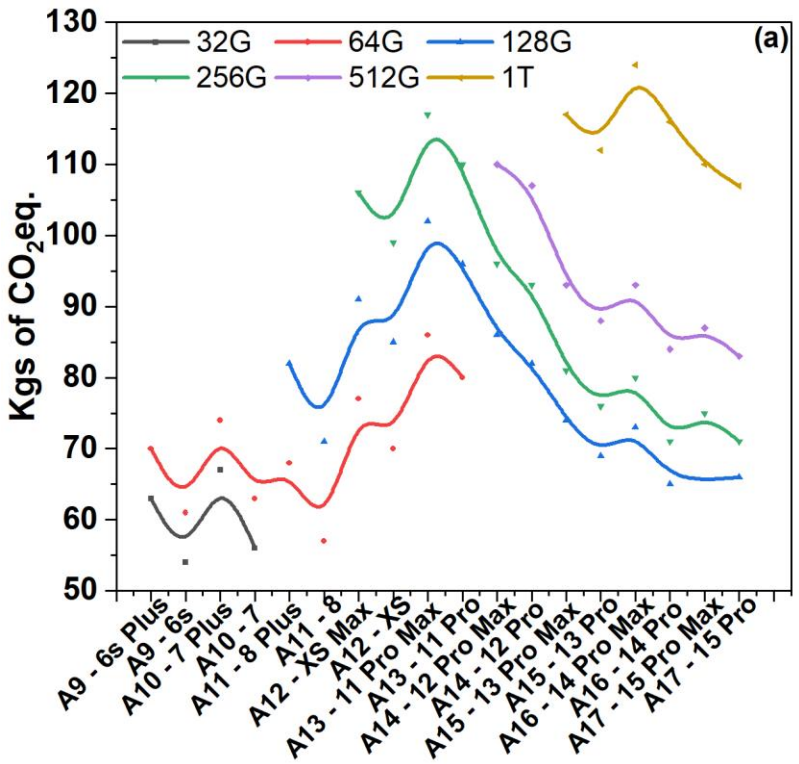
- CFP should be considered the primary optimization metric, alongside power, area, and performance (PPA)
- Advanced technology nodes require complex steps, including sophisticated lithography processes, which result in a higher CFP per unit area in the latest technologies

Transistors CFP contribution – CFP per billion transistor



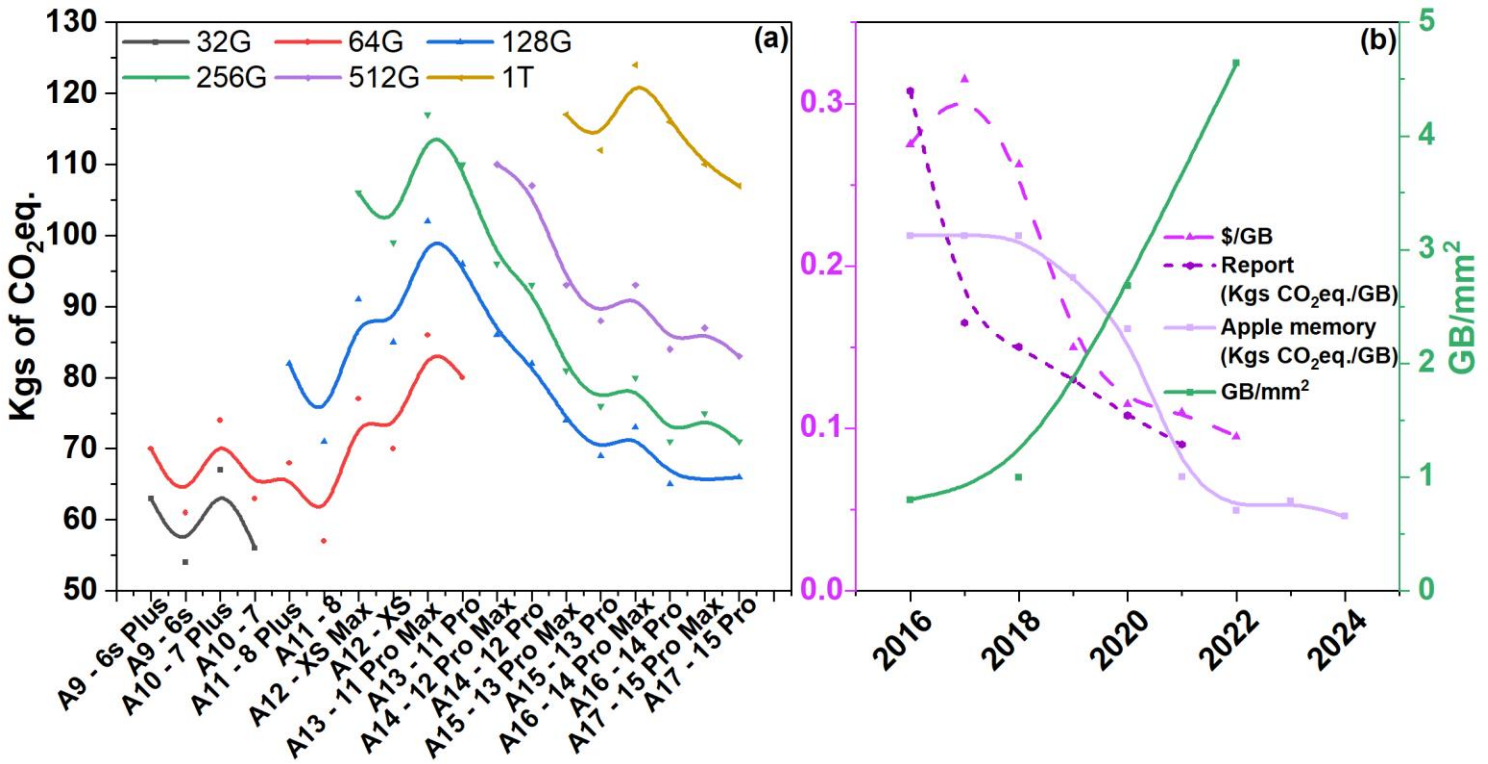
- CFP should be considered the primary optimization metric, alongside power, area, and performance (PPA)
- Advanced technology nodes require complex steps, including sophisticated lithography processes, which result in a higher CFP per unit area in the latest technologies

Mobile SSD CFP metric



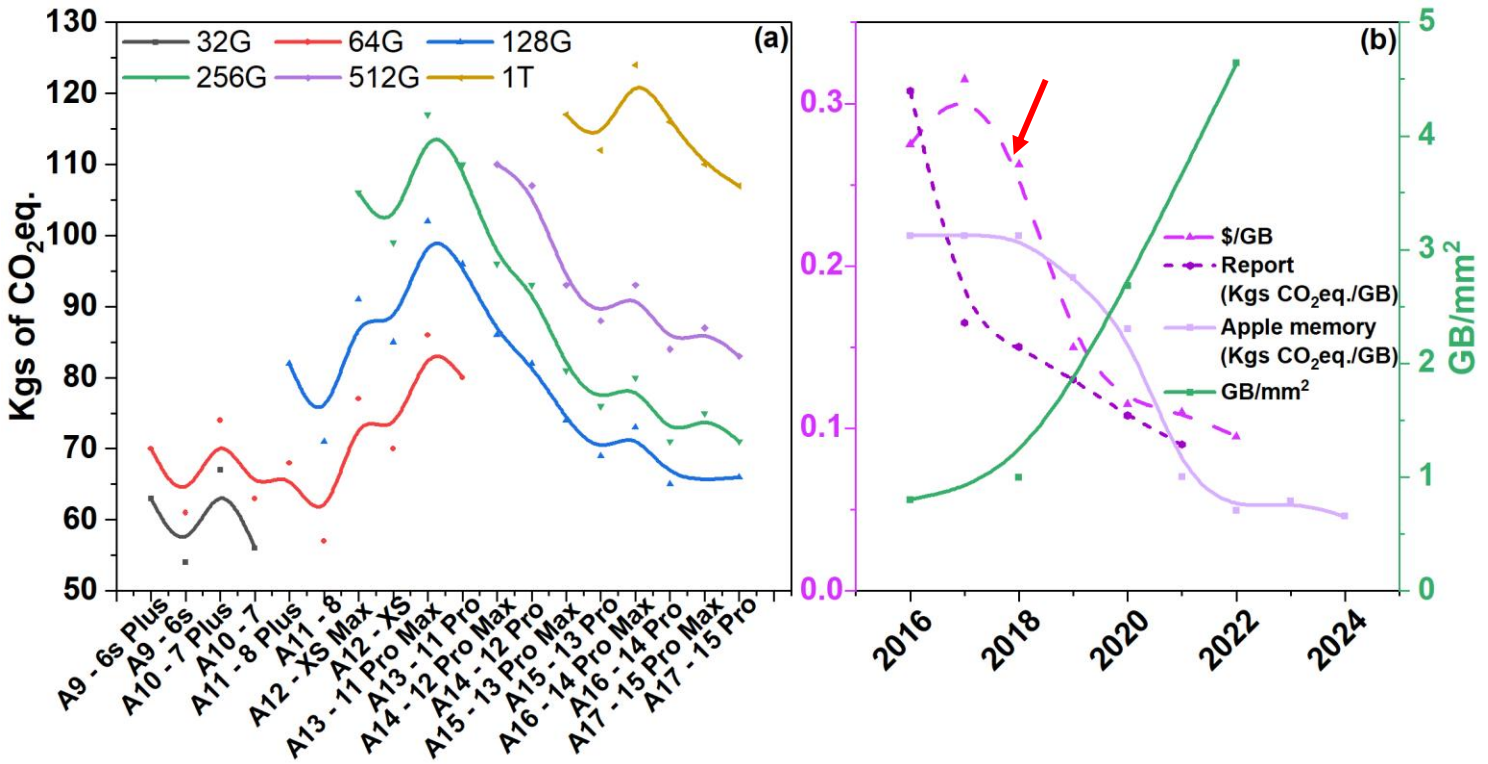
- Memory density (GB/mm^2) has increased over the years
- The increase in memory density offsets the CFP increase, resulting in CFP/GB to have a downward trend

Mobile SSD CFP metric



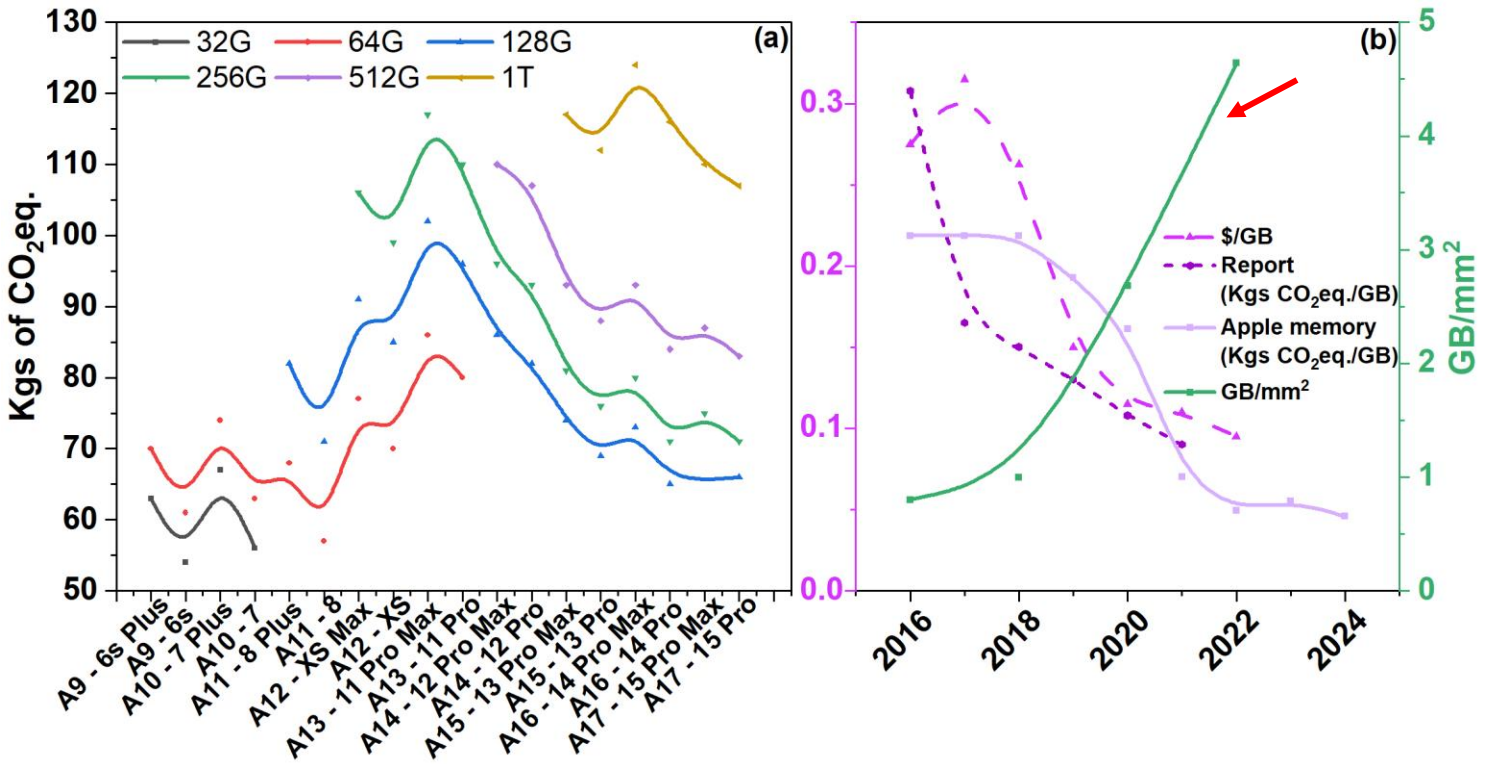
- Memory density (GB/mm^2) has increased over the years
- The increase in memory density offsets the CFP increase, resulting in CFP/GB to have a downward trend

Mobile SSD CFP metric



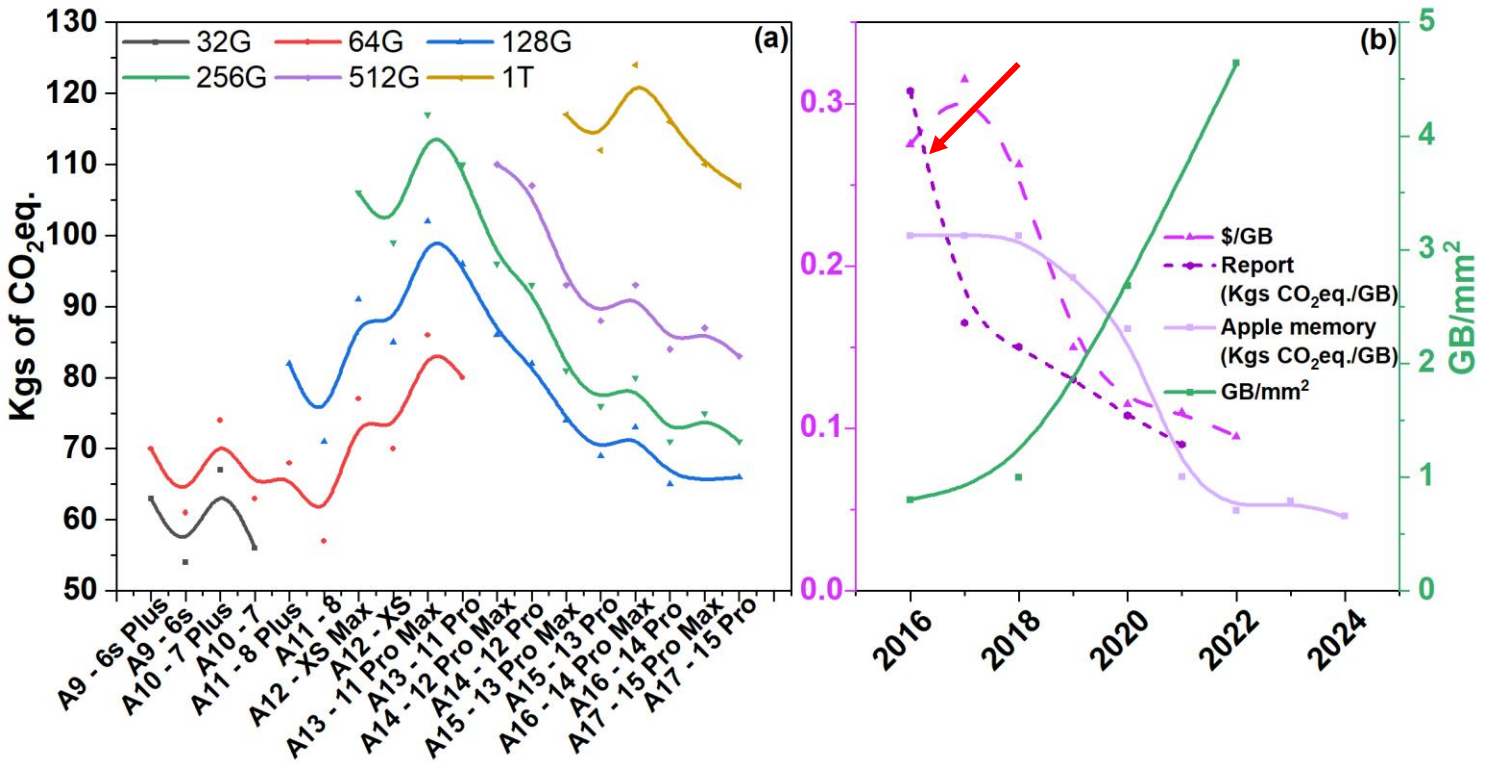
- Memory density (GB/mm^2) has increased over the years
- The increase in memory density offsets the CFP increase, resulting in CFP/GB to have a downward trend

Mobile SSD CFP metric



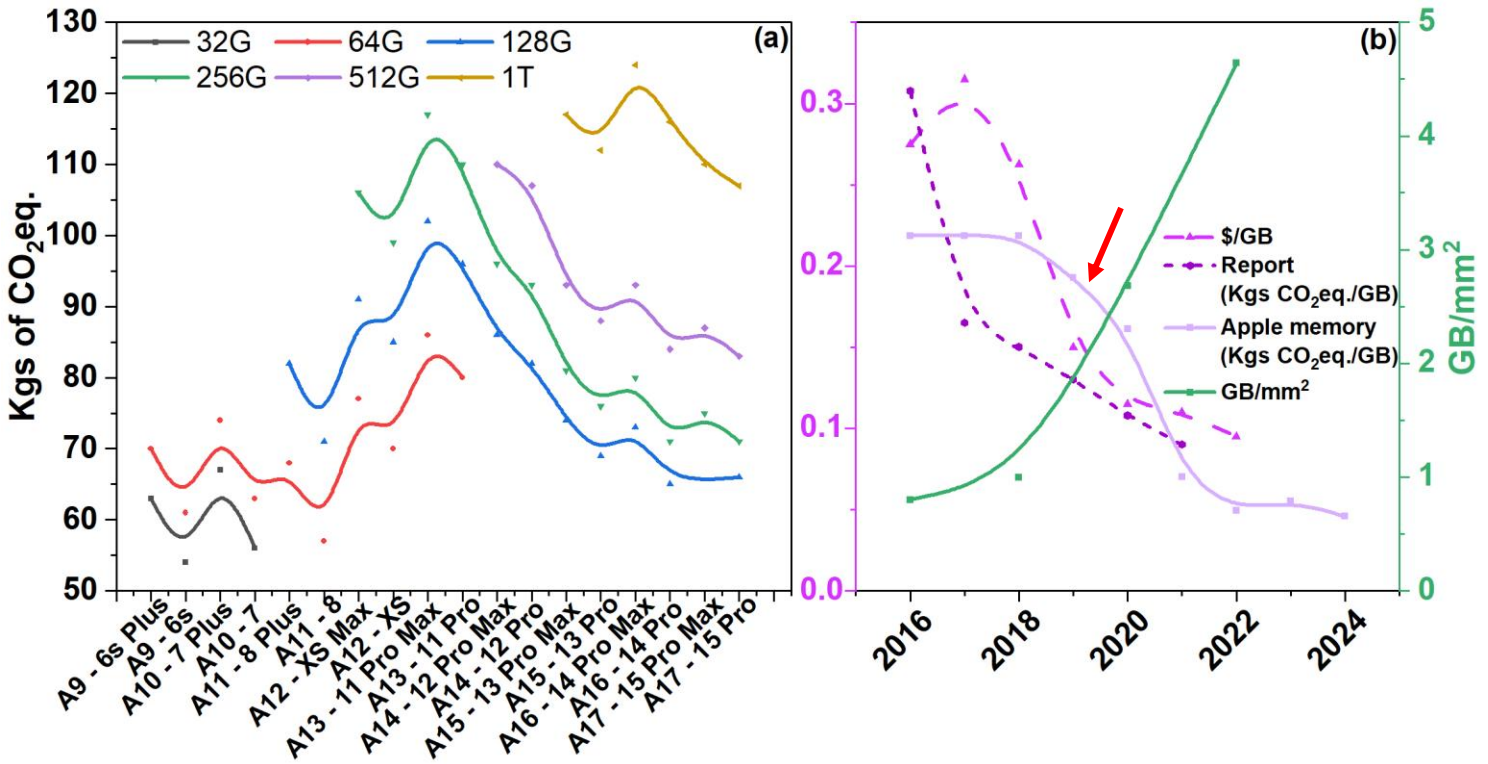
- Memory density (GB/mm^2) has increased over the years
- The increase in memory density offsets the CFP increase, resulting in CFP/GB to have a downward trend

Mobile SSD CFP metric



- Memory density (GB/mm^2) has increased over the years
- The increase in memory density offsets the CFP increase, resulting in CFP/GB to have a downward trend

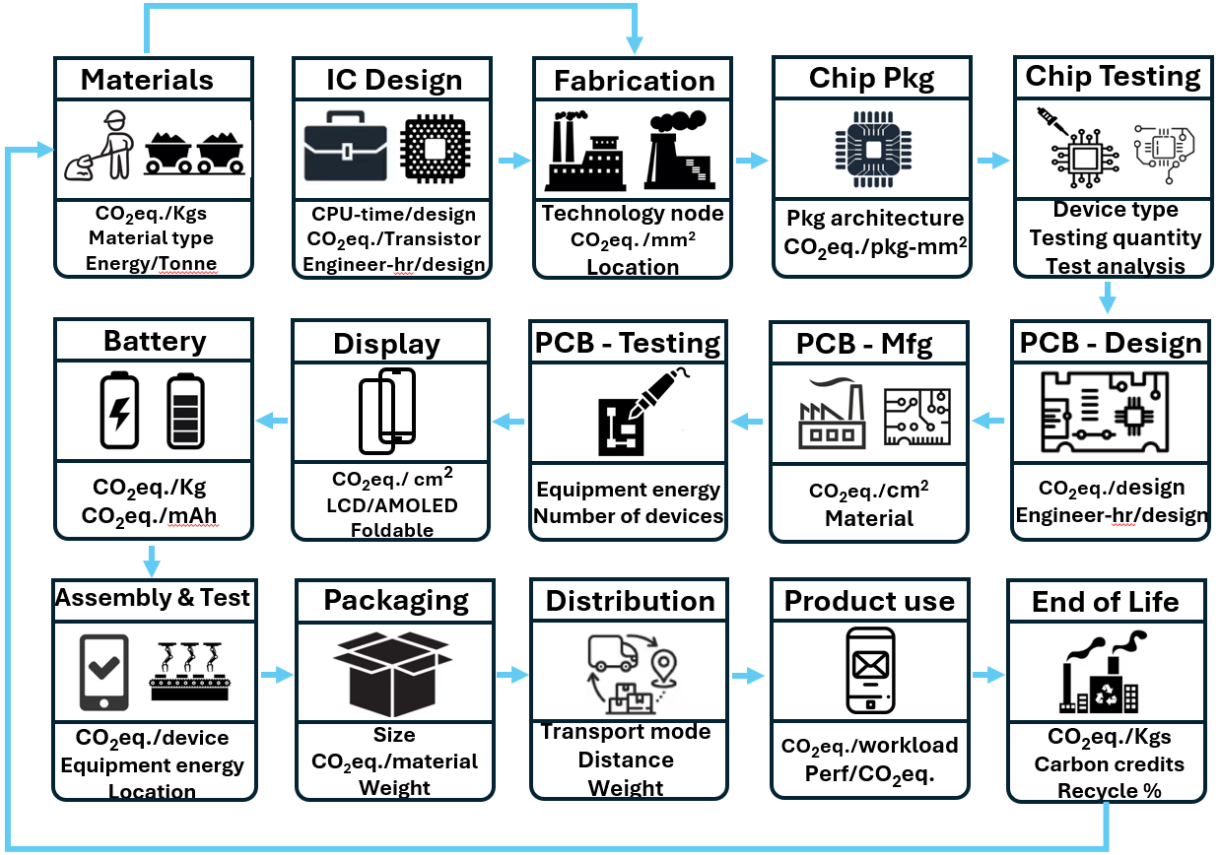
Mobile SSD CFP metric



- Memory density (GB/mm^2) has increased over the years
- The increase in memory density offsets the CFP increase, resulting in CFP/GB to have a downward trend

Conclusion

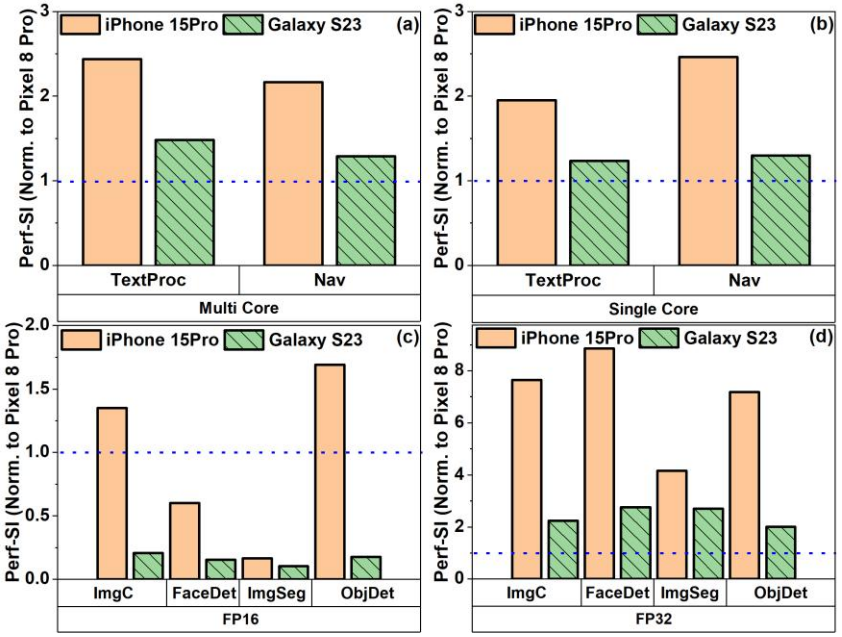
Objective 1: Call to action** for the **industry** to include **detailed data in sustainability reports

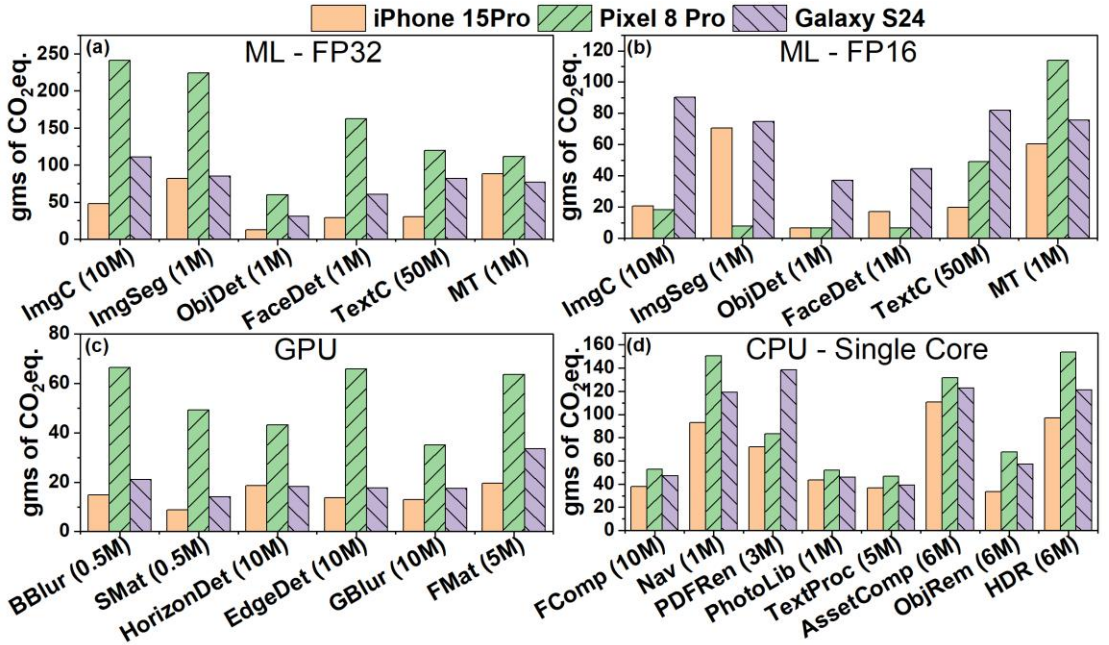


Conclusion

Objective 1: Call to action** for the **industry** to include **detailed data in sustainability reports

***Objective 2: Call to action** for the **community** to incorporate **sustainability-oriented** metrics for benchmarking chips and architectures*





Thank you