



Rekayasa PL Hijau: Peluang dan Tantangan

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ITS
Institut
Teknologi
Sepuluh Nopember

An abstract digital illustration with a green color scheme. It features several 3D cubes and rectangular blocks arranged in a perspective view. The surfaces of these shapes are covered with a pattern of binary code (0s and 1s). Bright green and blue light sources, resembling stars or data points, are scattered throughout the scene, casting a soft glow. The overall effect is a sense of depth and digital complexity.

Green Software Engineering

What?

Green Software Engineering focuses on developing software that is energy-efficient and minimizes environmental impact.

It involves optimizing code, reducing energy consumption, and using sustainable computing resources.



Green Software Engineering

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How?

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How?

It involves optimizing code, reducing energy consumption, and using sustainable computing resources.

Apakah Industri Sw
Berdampak kepada
Lingkungan

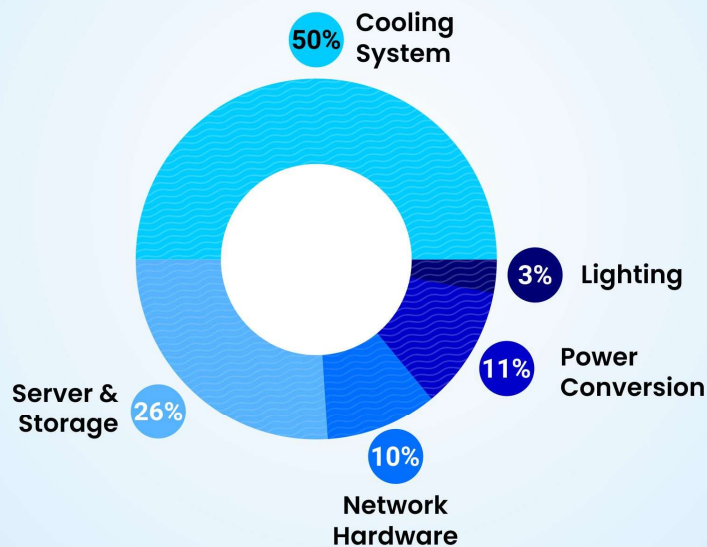
Colossal Data Center



Apakah Industri Sw Berdampak kepada Lingkungan

Colossal Data Center

A Breakdown of Energy Consumption by Different Components of a Data Center

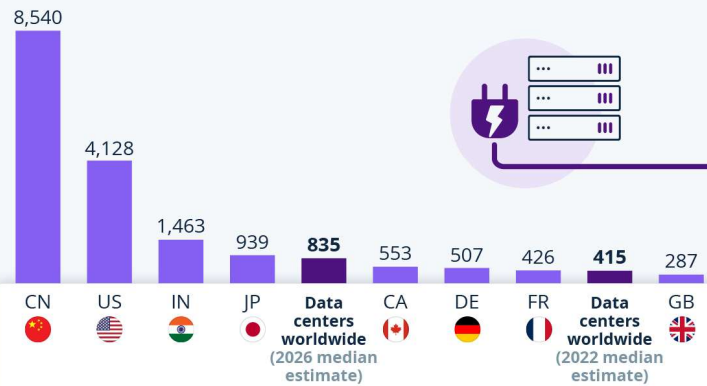


Source - ieeexplore.ieee.org

StratView[®]
Research
Strategic Insights. Data Driven.

Data Centers and Their Increasing Energy Appetite

Estimated electricity consumption of data centers* compared to selected countries in 2022, in TWh



* AI, cryptocurrencies, traditional data centers

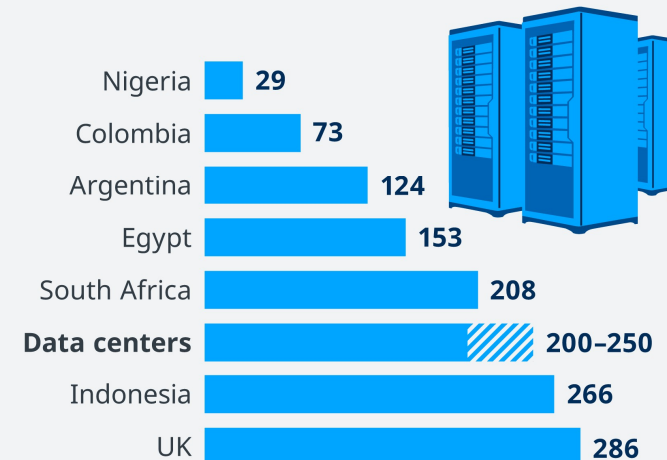
Sources: U.S. Energy Information Administration, IEA



statista

Data centers use more electricity than entire countries

Domestic electricity consumption of selected countries vs. data centers in 2020 in TWh



Source: Enerdata, IEA

Apakah Industri Sw
Berdampak kepada
Lingkungan

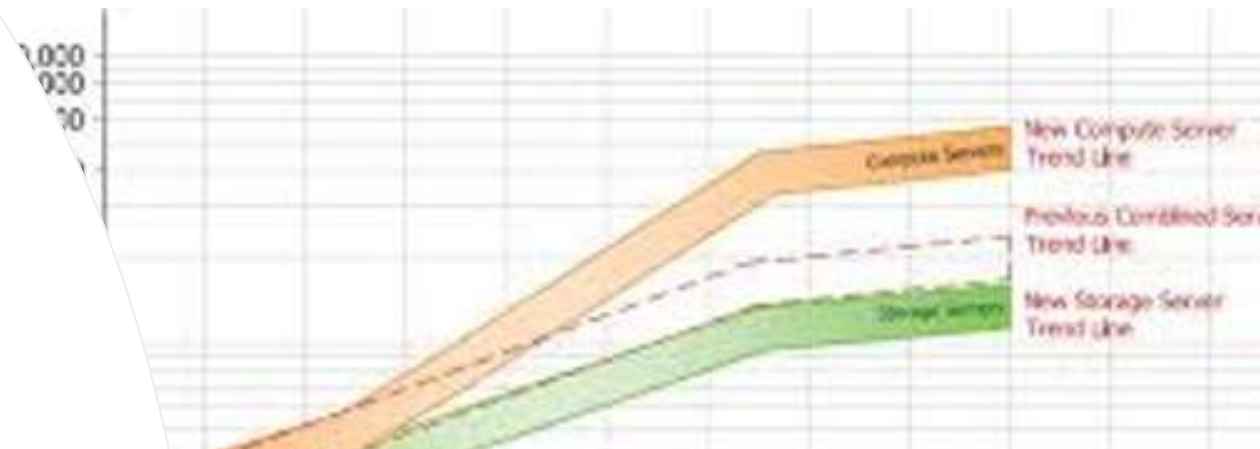
Colossal Data Center



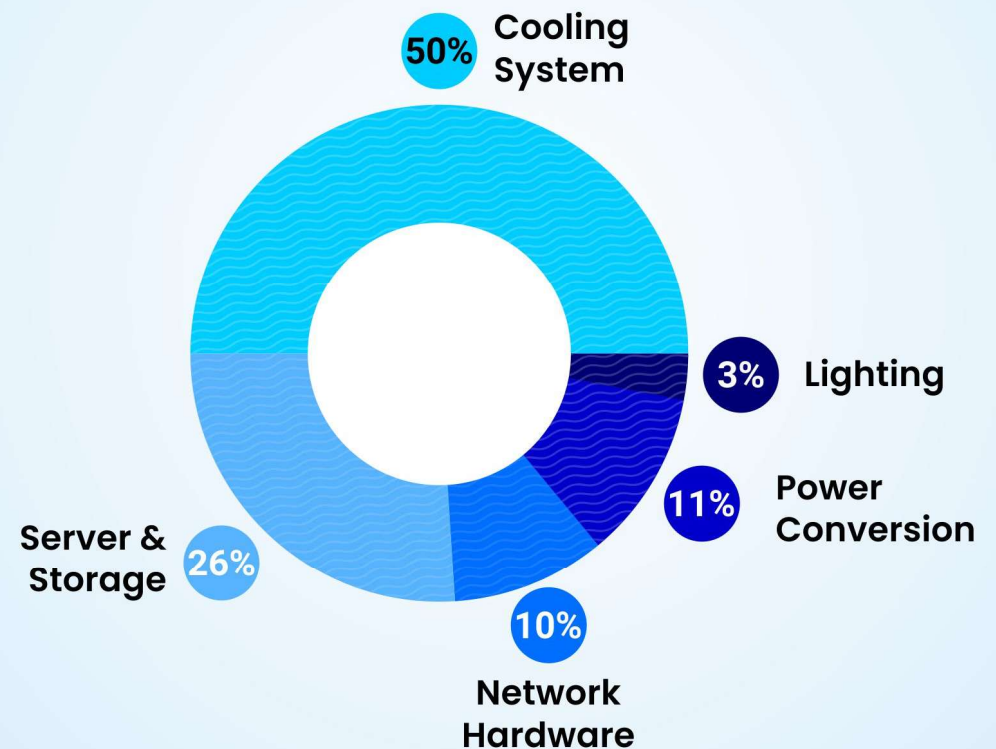
Vast Electricity Consumption



Generate Heat



A Breakdown of Energy Consumption by Different Components of a Data Center



Source - ieeexplore.ieee.org

Apakah Industri Sw
Berdampak kepada
Lingkungan

Colossal Data Center



Vast Electricity Consumption

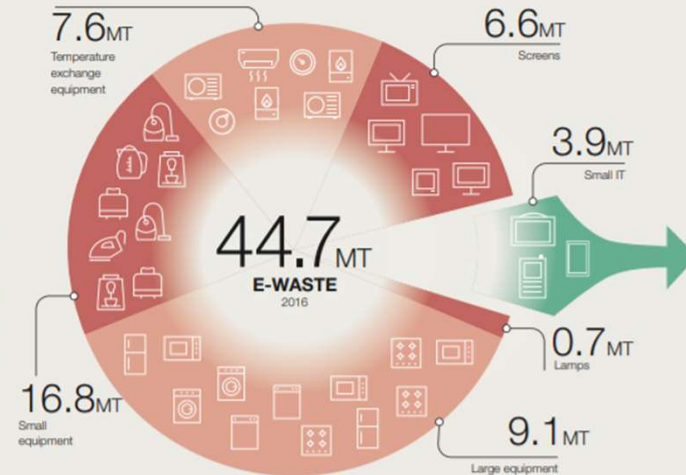


Generate Heat

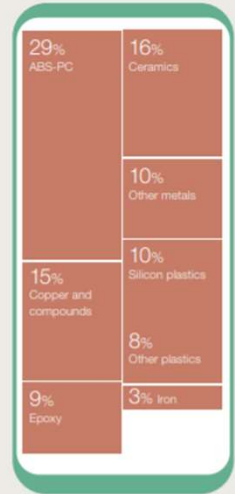


E-Waste

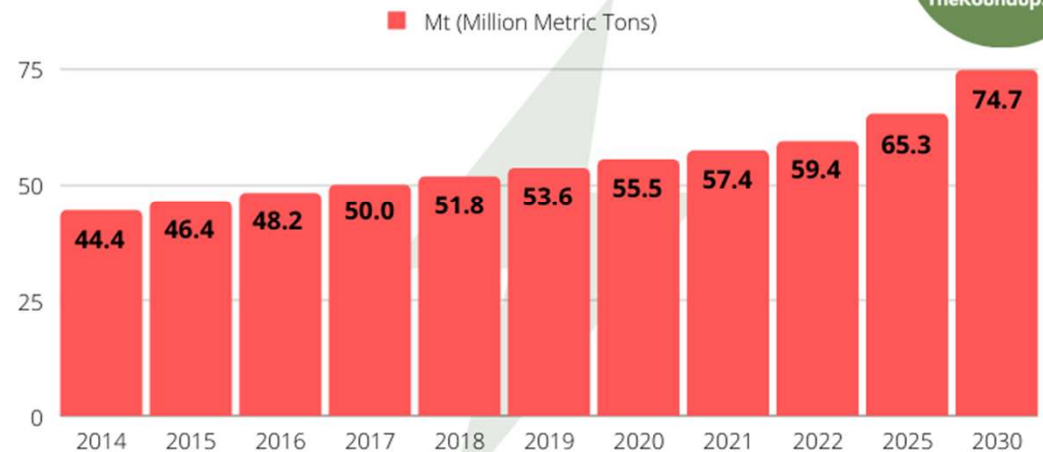
WHAT IS E-WASTE?



What's in a typical mobile phone?



Total Annual Global E-WASTE GENERATION

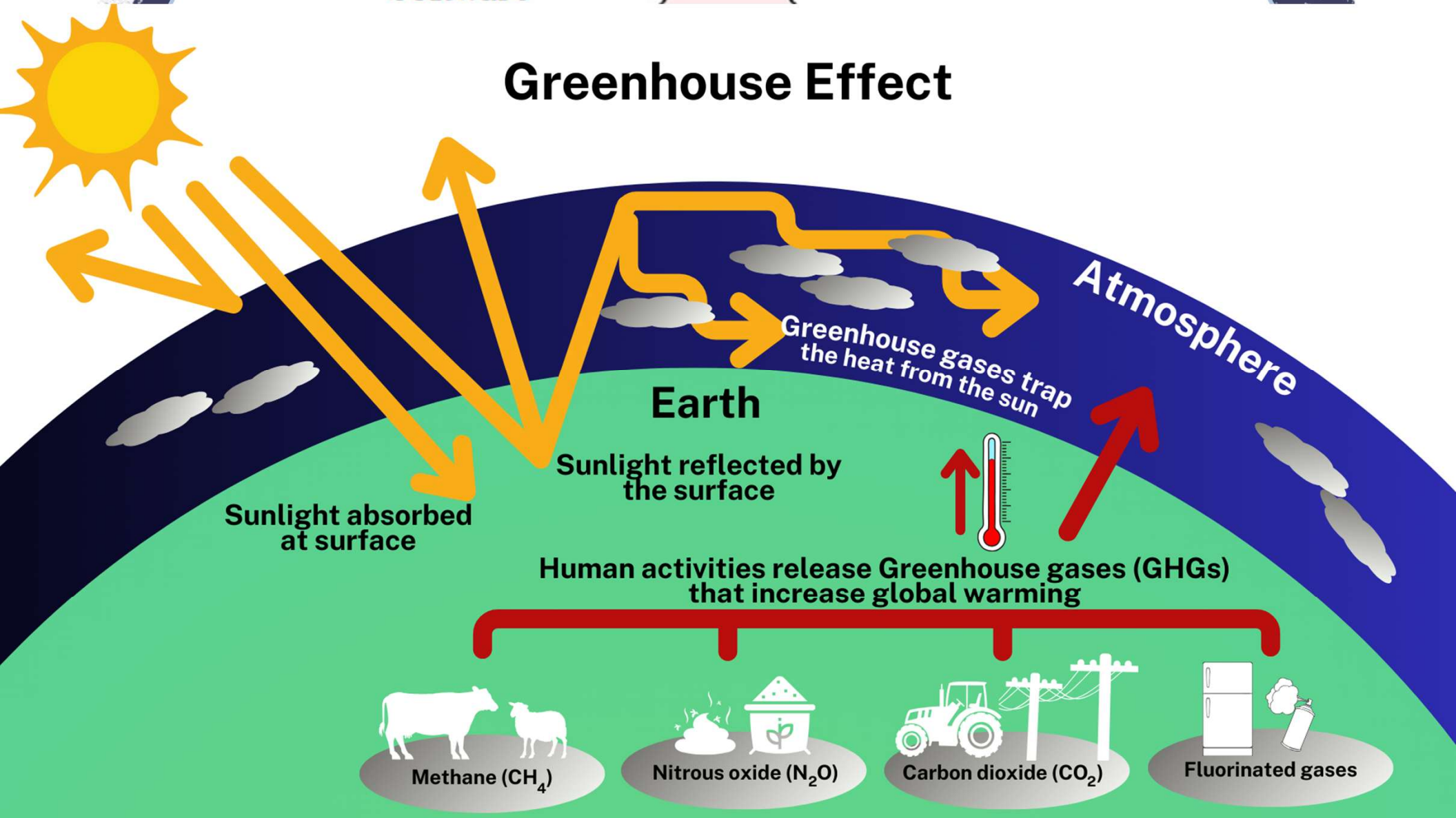


E-Waste Monitor

THEROUNDUP.ORG

Sustainable
Software

Greenhouse Effect





8 Principles of GSE



Carbon-efficient



Lower Electricity Consumption



Lower Carbon Intensity



Lower Embodied Carbon



Higher Energy Proportionality



Incremental Optimization



Demand Shaping



Efficient Networking

8 Principles of GSE

Filosofi dari



Everyone Has a Role

Sustainability is the Key

GSE?



Mengapa GSE Penting?

Reduces carbon
footprint of IT
infrastructure

Enhances energy
efficiency in data
centers

Promotes
sustainable
computing
practices

Helps organizations
meet
environmental
regulations

Manfaat GSE?



SIMPLER
ARCHITECTURE



FASTER
COMPUTING SPEED

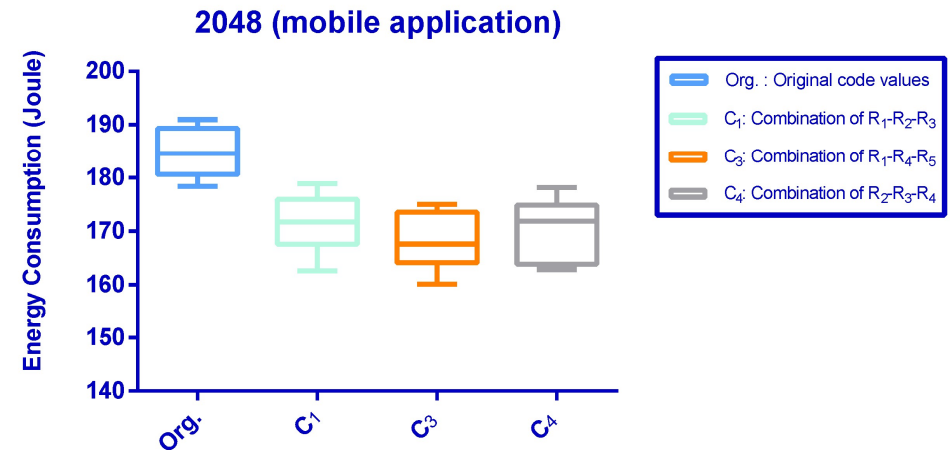
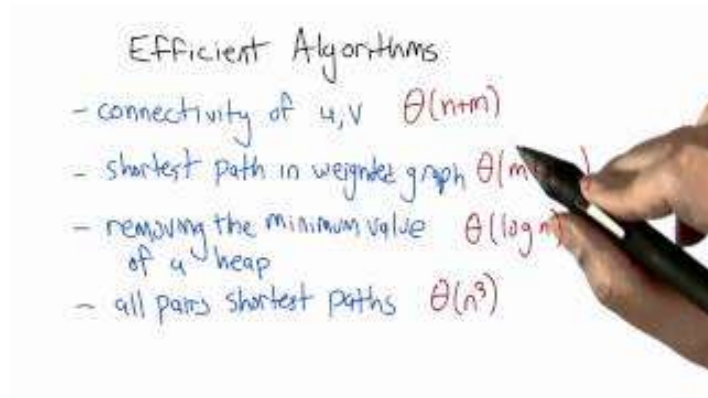


LOW RESOURCE
USAGE

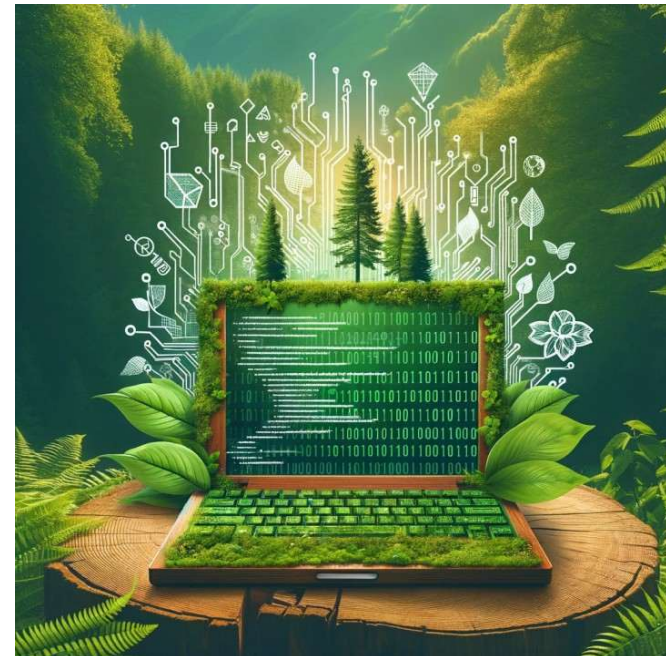
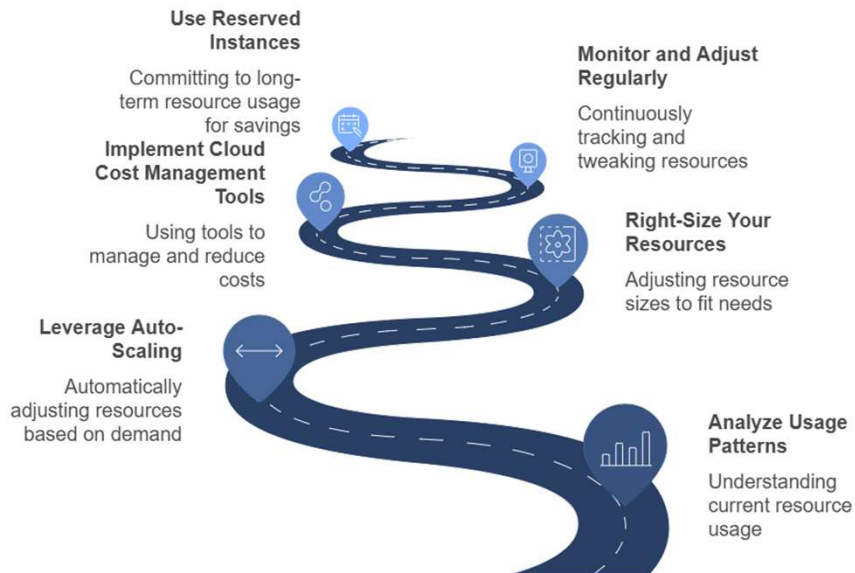


BRAND RESILIENCE

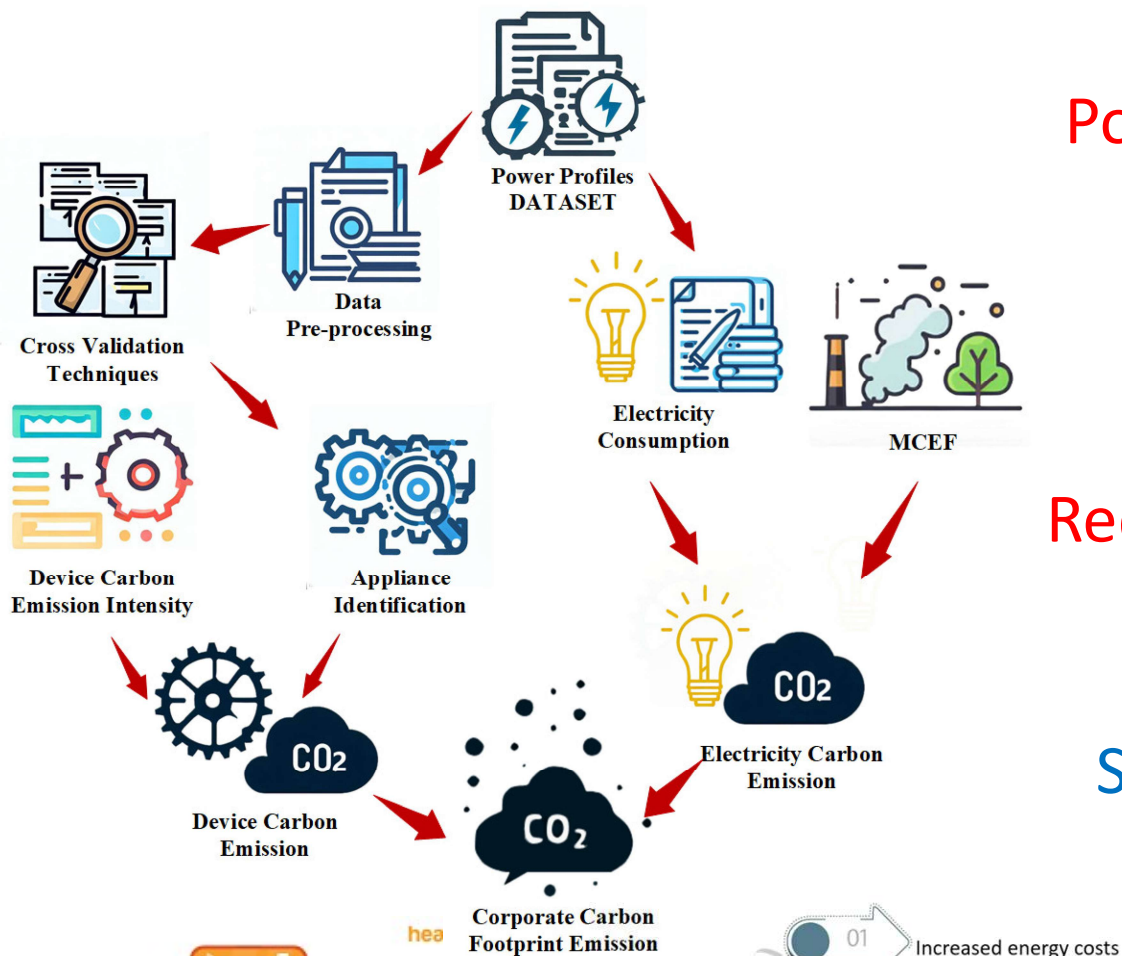
SUSTAINABLE CODING: BEST PRACTICES



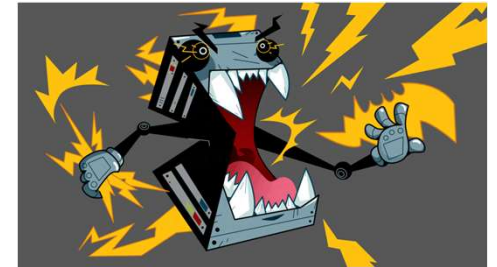
Steps to Optimize Cloud Usage



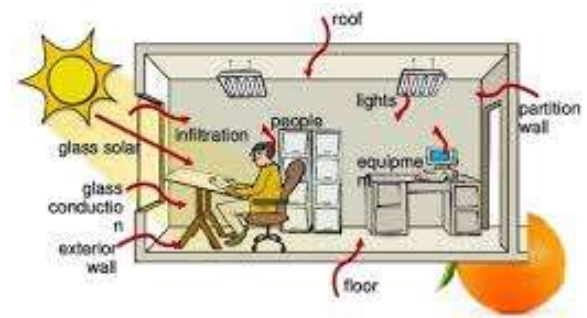
Coding & Carbon Footprints



Power Hungry
Data Center



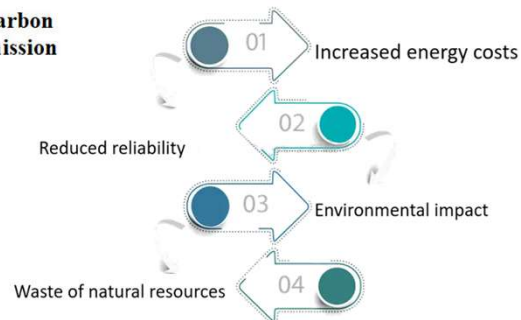
Cooling
Requirements



Scalability &
Longevity

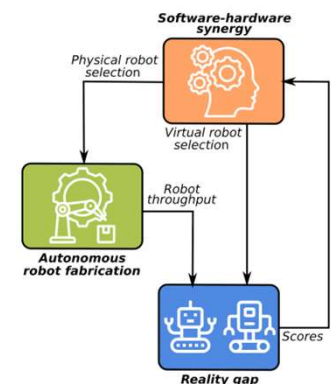


Optimized
Mobile Apps

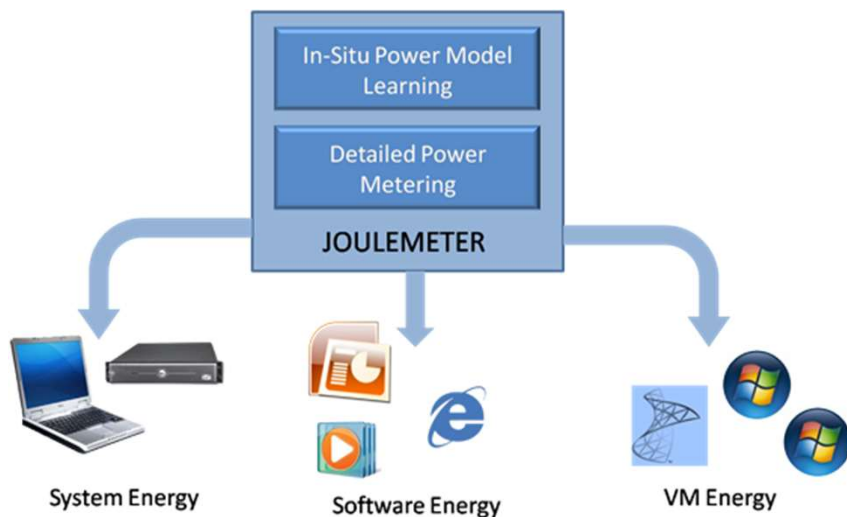


Reduction
Transmission Energy

Sw – Hw
Synergy

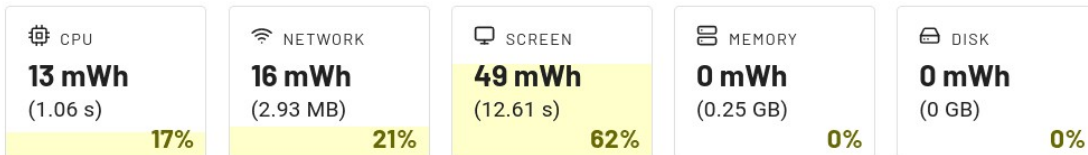


Tools for GSE

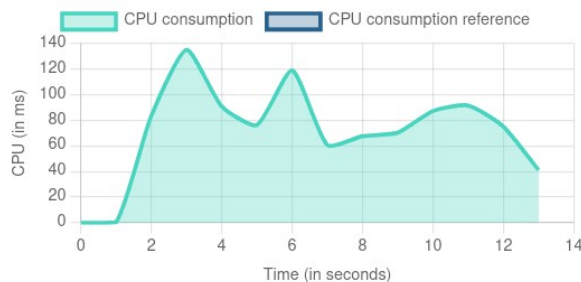


GreenFrame browser

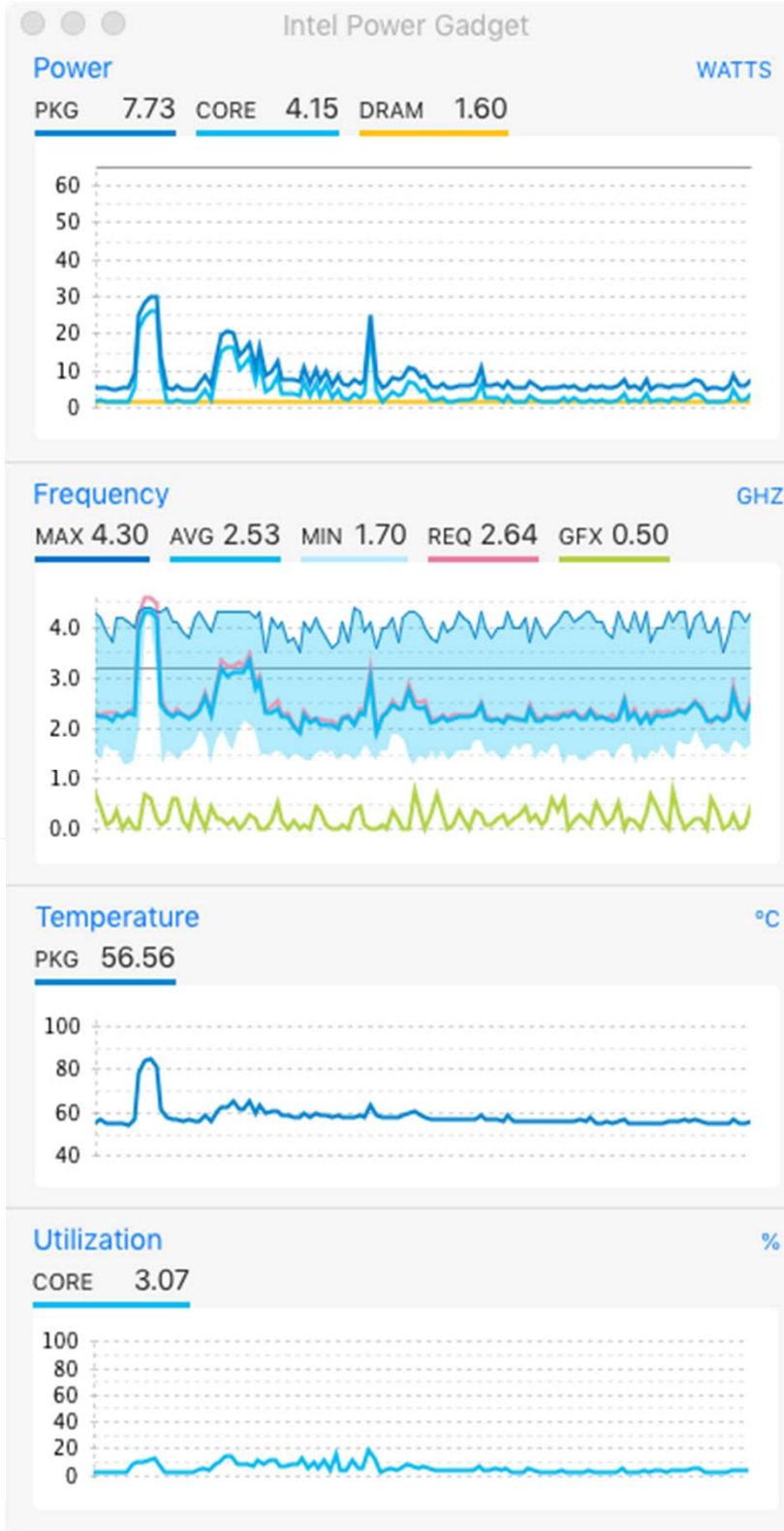
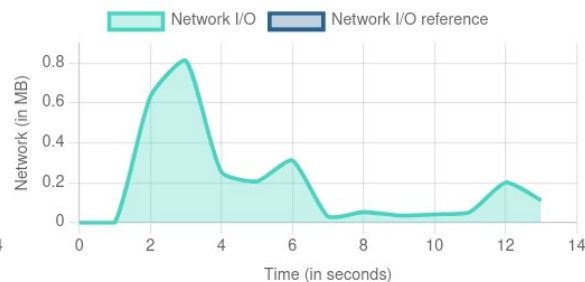
⚡ 79 mWh 🌱 35 mg eq. CO₂



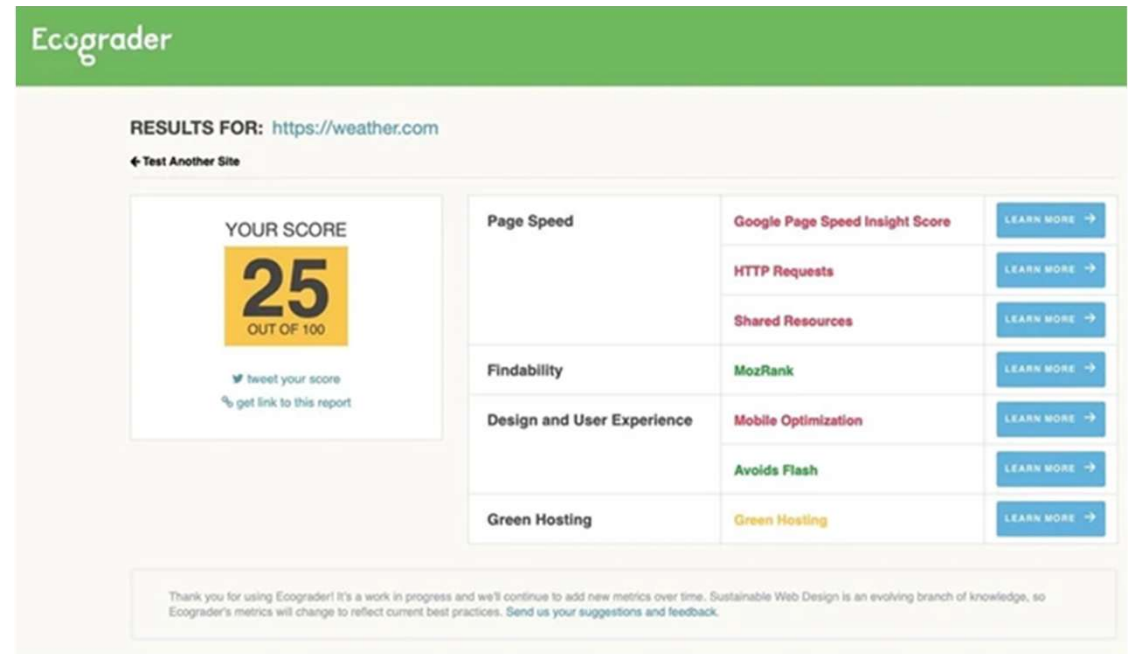
CPU



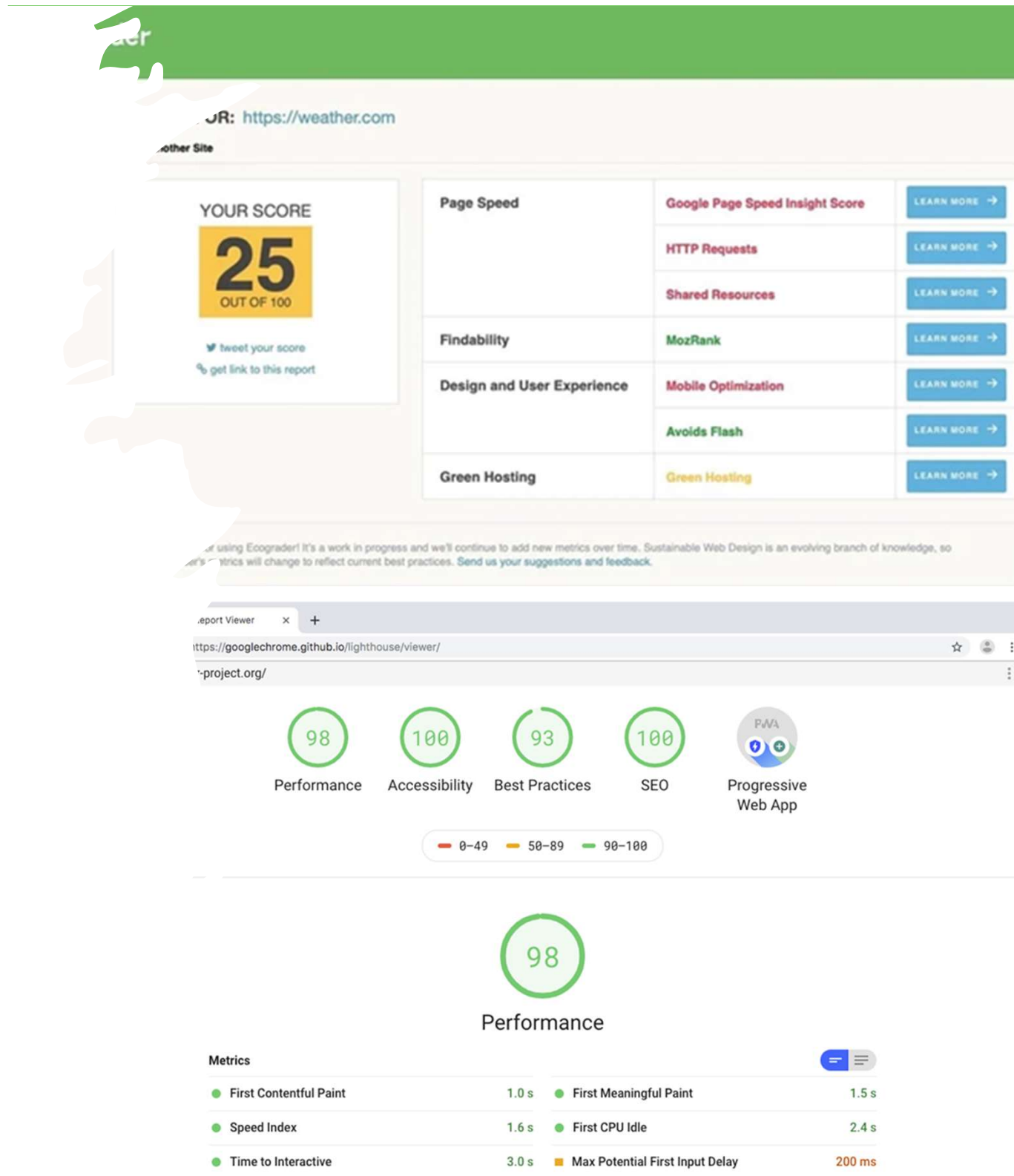
Network



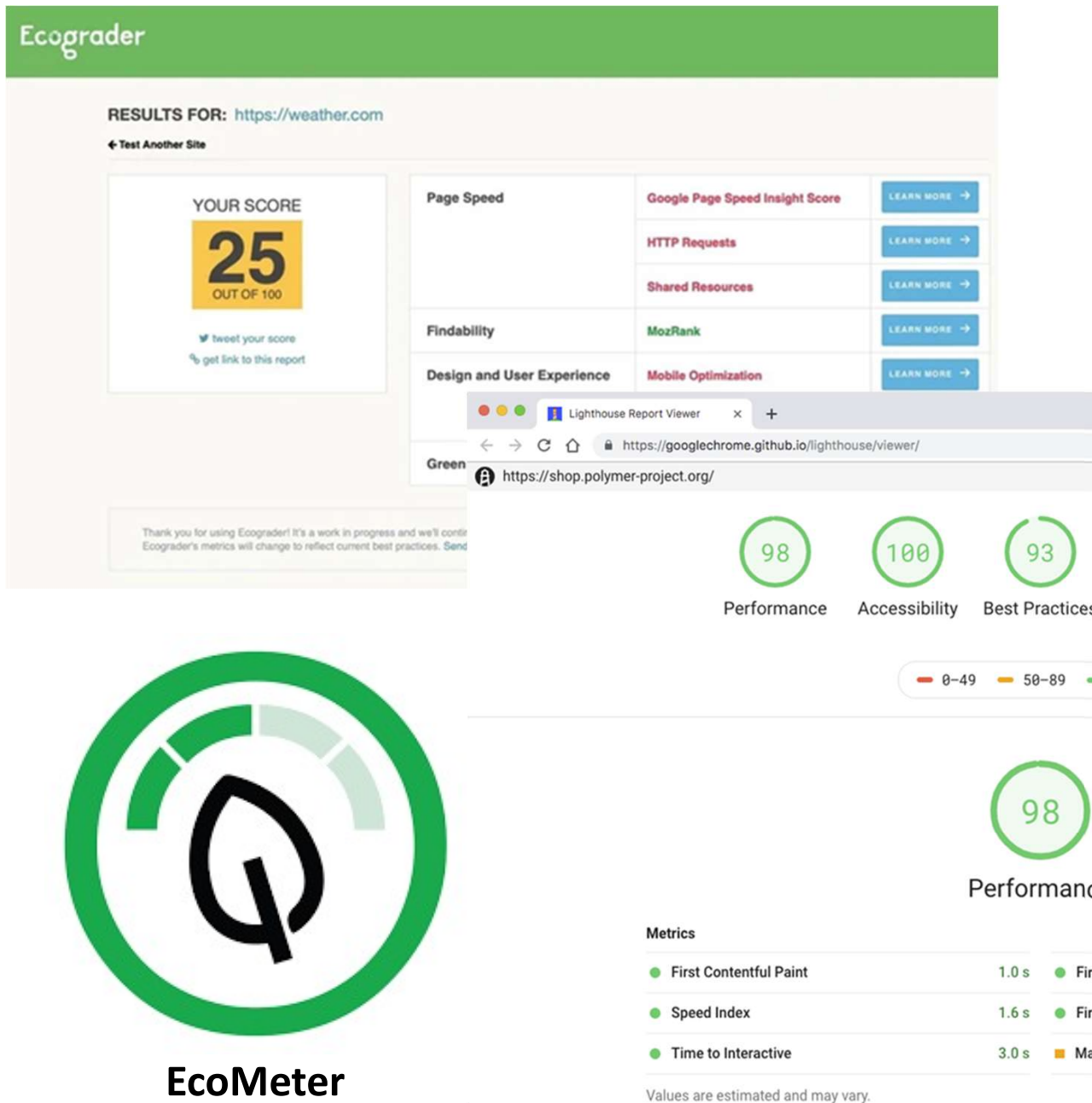
Tools for GSE



Tools for GSE



Tools for GSE

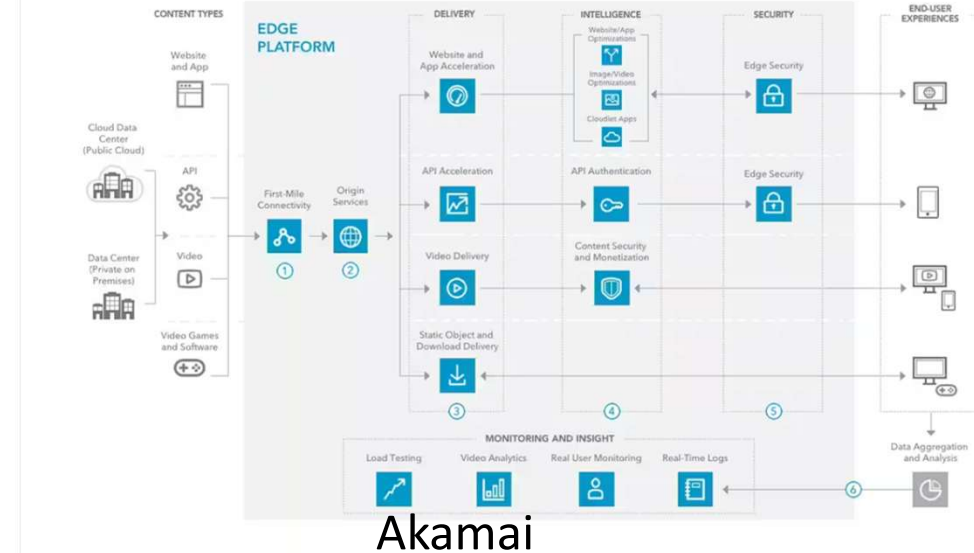
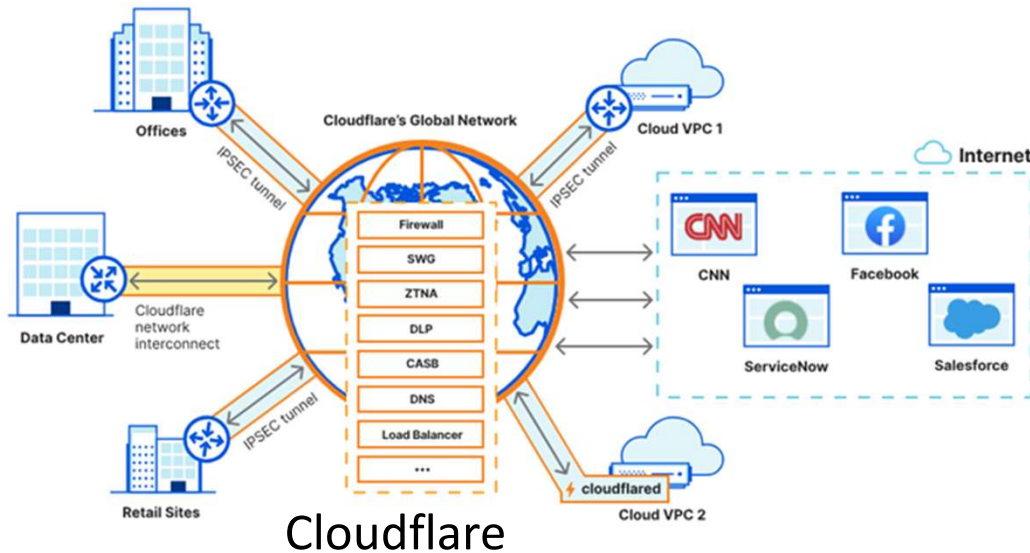




Tools for GSE



Tools for GSE



Case Studies in Green Software

- Google's energy-efficient data centers
- Microsoft's carbon-negative initiatives
- Sustainable software development at IBM
- Green AI models reducing computation power

Industry Impact of Green Software

- IT industry's role in reducing carbon emissions
- Green coding initiatives in major tech firms
- Policy and regulatory trends towards sustainability
- Future of eco-friendly software development

CLOUD COMPUTING AND GREEN CODING

- **Efficiency at Its Core**
- **Reduced Carbon Footprint**
- **Scale with Care**
- **Less Waste**

ROLE OF AI IN GREEN CODING



**OPTIMIZATION
ALGORITHMS**



**PREDICTIVE
ANALYTICS**



**AUTOMATED GREEN
TESTING**



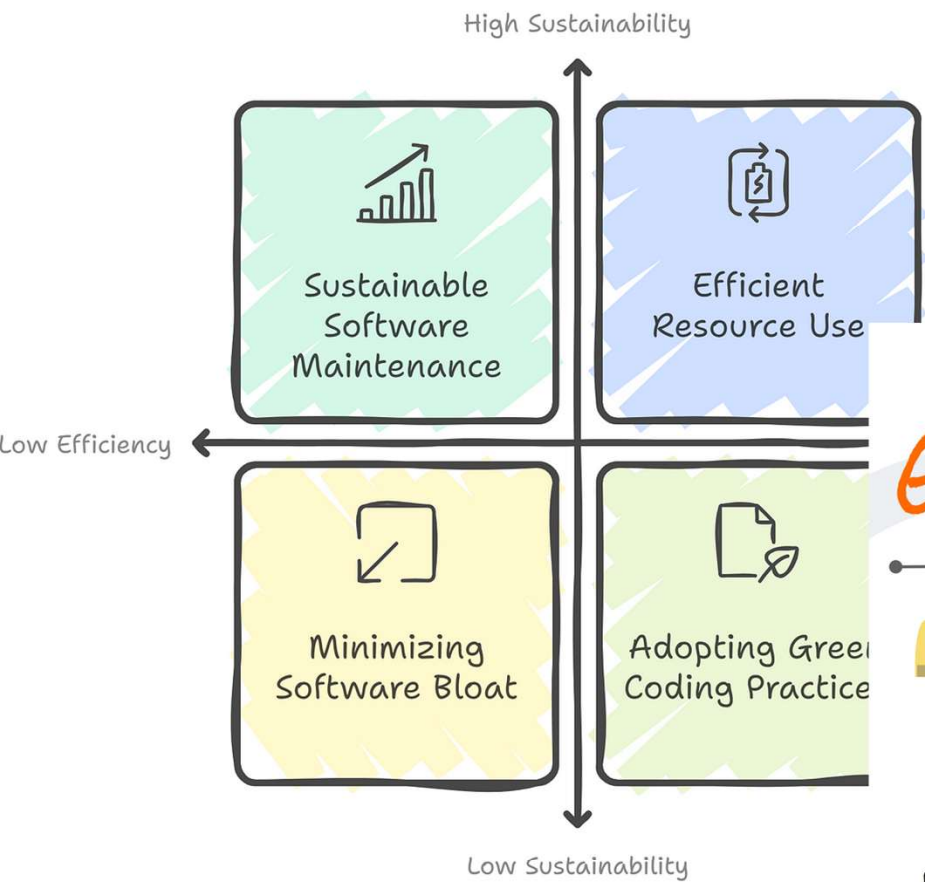
**DYNAMIC
RESOURCE
ALLOCATION**



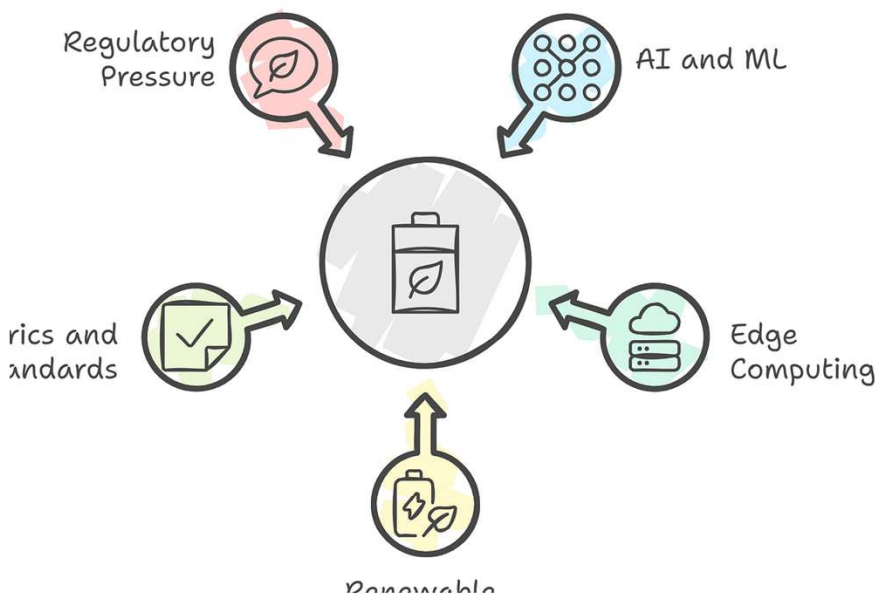
**TAILORED LEARNING
RESOURCES**

What Future Holds

Green Software Design Strategies

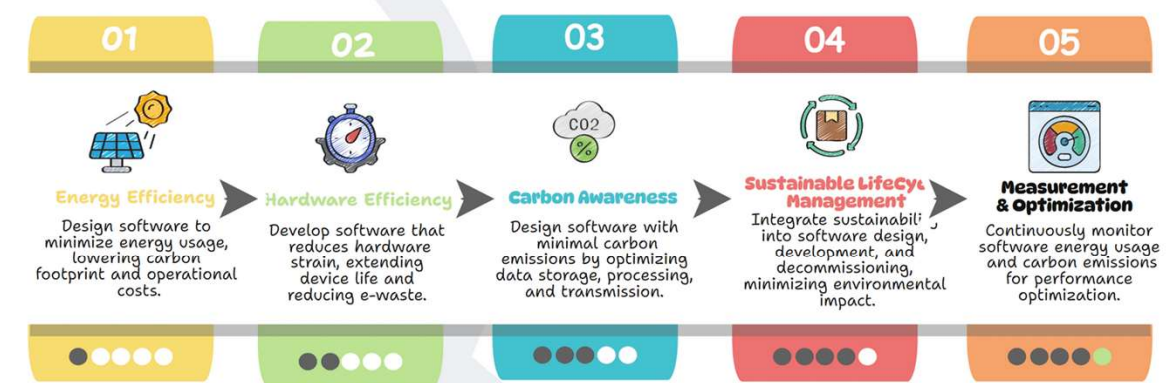


Future Directions in Green Software Architecture



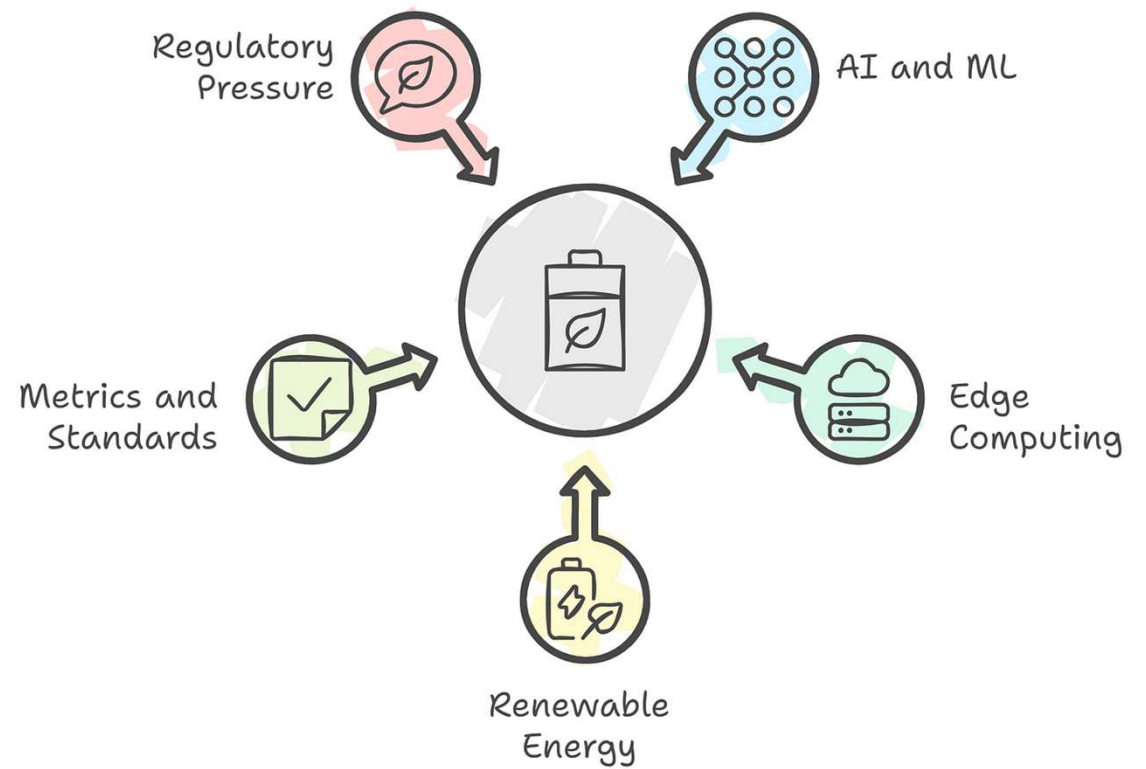
Principles

GREEN SOFTWARE ARCHITECTURE



What
Future
Holds

Future Directions in Green Software Architecture



Green Coding

Algoritma dan Struktur Data Yang Efisien

Linear Search

```
def count_elements_linear(arr, element):  
    count = 0  
    for i in range(len(arr)):  
        if arr[i] == element:  
            count += 1  
    return count
```

Hash Table Search

```
def count_elements_hash_table(arr, element):  
    count_table = {}  
    for i in range(len(arr)):  
        if arr[i] in count_table:  
            count_table[arr[i]] += 1  
        else:  
            count_table[arr[i]] = 1  
    if element in count_table:  
        return count_table[element]  
    else:  
        return 0
```

Green Coding

Energy-Efficient Hardware

No-Memoization

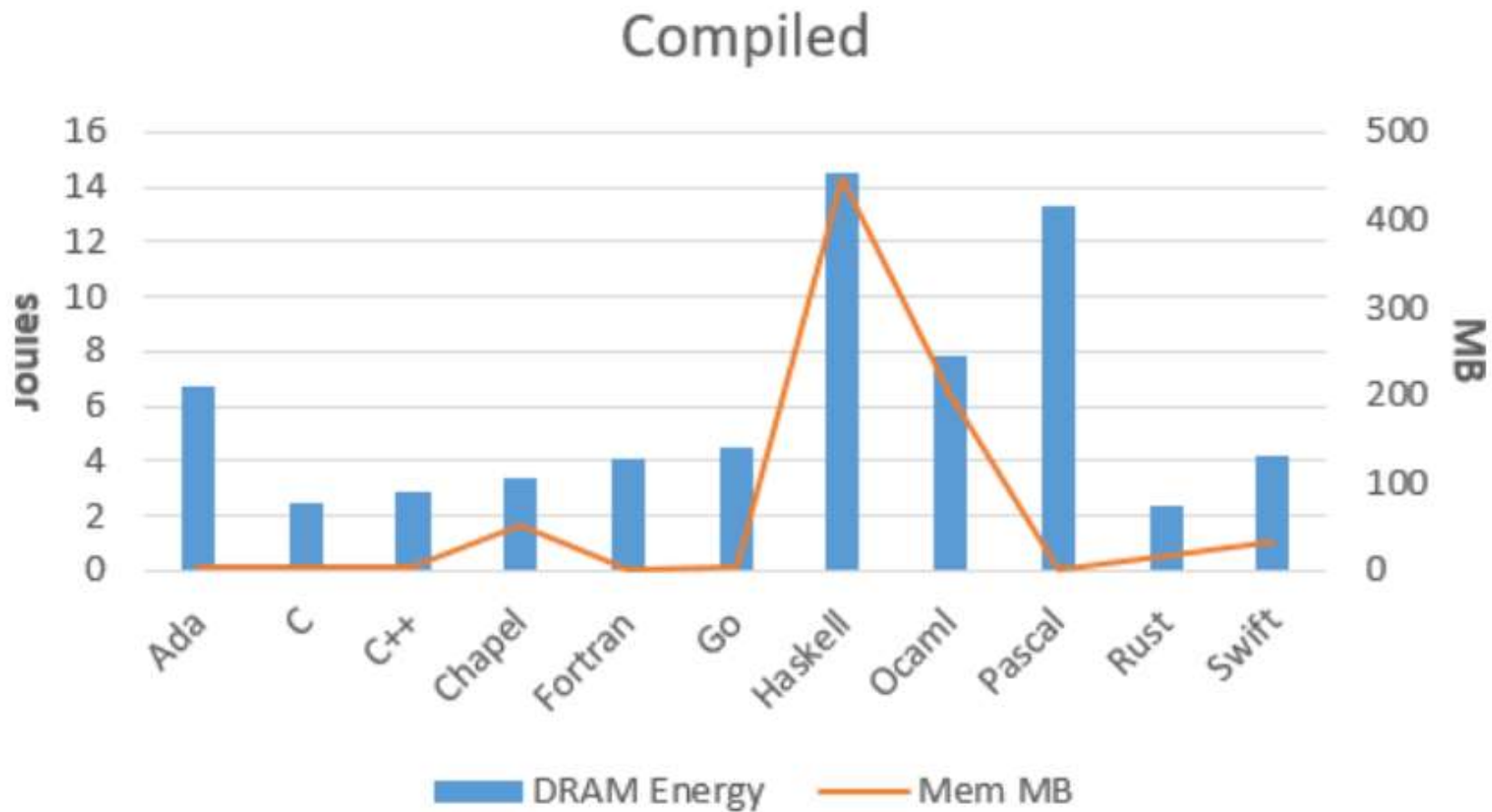
```
def fibonacci_recursive(n):  
    if n < 2:  
        return n  
    return fibonacci_recursive(n-1) +  
    fibonacci_recursive(n-2)
```

With Memoization

```
def fibonacci_memoization(n, memo):  
    if n in memo:  
        return memo[n]  
    if n < 2:  
        memo[n] = n  
    else:  
        memo[n] = fibonacci_memoization(n-1, memo)  
    + fibonacci_memoization(n-2, memo)  
    return memo[n]  
  
def fibonacci(n):  
    memo = {}  
    return fibonacci_memoization(n, memo)
```

Green Coding

Energy-Efficient Programming Language



Green Coding

Energy-Efficient Programming Language

	Energy consumed	Run-time
C	57J	2019 ms
Rust	59J	2103 ms
C++	77J	3155 ms
Ada	98J	3740 ms
Java	114J	3821 ms

<i>Language</i>	<i>Memory space needed</i>
Pascal	66Mb
Go	69Mb
C	77Mb
Fortran	82Mb
C++	88Mb

Green Coding

Energy-Efficient Programming Language

	Energy consumed	Run-time
Imperative	125J	5585ms
Object-Oriented	879J	32965ms
Functional	1367J	42740ms
Scripting	2320J	88322 ms