# Sustainable Cloud Computing and 5G Network – Revision Notes

## Sustainable Cloud Computing – Key Concepts

### Definition

- **Sustainable Cloud Computing**: Approach aimed at **minimizing energy consumption, carbon footprints**, and **ensuring reliability** of Cloud Data Centers (CDCs).

### Energy Consumption Facts

- CDCs' energy usage is **increasing**, expected to reach **8000 TWh by 2030**.
- **Main energy-consuming components**:
  - Processor: **45%**
  - Memory: **15%**
  - Storage: **10%**
  - Network: **10%**
  - Cooling: **20%**

### Sustainable Cloud Architecture - Layers

1. **SaaS** – Software as a Service
2. **PaaS** – Platform as a Service
3. **IaaS** – Infrastructure as a Service

### Cooling Manager

- Generates **thermal alerts** when temperatures exceed thresholds.
- Uses **heat controllers** to maintain performance with **minimal cooling impact**.

### Reliability & Sustainability Issues

#### Energy Goals:

- Reduce energy usage and **carbon emissions**
- Improve **load balancing** (prevent under/overloading)
- Optimize **bandwidth, storage**, and **disk management**

#### Reliability Goals:

- Minimize **SLA violations**
- Prevent **service delays**
- Ensure **secure VM migration**
- Use **encryption/decryption** for communication
- Identify **failures** and enhance **system robustness**

### Reliability ↔ Sustainability Implication

- **Frequent server on/off** reduces reliability (affects memory, storage).
- Need for **energy-aware resource management** without reliability loss.

## Key Components of Sustainable Cloud Computing

### Application Model

- Efficient app design improves energy use.
- Types: **Data Parallel**, **Function Parallel**, **Message Passing**.

### Thermal-Aware Scheduling

- Manages **cooling set-point**, **hotspots**, **thermal gradient**.
- Types:
  - **Architecture**: Single-core / Multi-core
  - **Scheduling**: Reactive / Proactive
- Focus: Reduce **Power Usage Efficiency (PUE)** and cooling cost.

### Virtualization

- **VM migration** balances load and uses **renewable energy** effectively.
- Enables **workload shifting** to CDCs using **waste heat** or **renewables**.

### Capacity Planning

- Aim: Maximize **ROI** and resource utilization.
- Merge compatible apps to reduce capacity cost.
- Analyze workloads for **deadline-oriented execution**.

### Renewable Energy

- Sources: **Solar, Wind**
- Optimized by: **Location**, **Energy Storage**, **On/Off-site**
- Challenges: **Unpredictability, high capital cost**
- Solved by: **Workload migration**, **energy-aware balancing**

**Waste Heat Utilization**

- Uses **vapor-absorption cooling**.
- Reduces **cooling expenses** and increases energy efficiency.

**Cloud Computing in 5G**

**Generations Overview**

| Generation | Feature |
|---|---|
| **1G** | Analog voice |
| **2G** | Digital voice (CDMA) |
| **3G** | Mobile data (CDMA2000) |
| **4G LTE** | Mobile broadband |
| **5G** | High speed, ultra-low latency, massive connectivity |

**5G Features**

- **eMBB**: Enhanced Mobile Broadband – AR/VR, collaboration
- **mMTC**: Massive Machine-Type Communications – IoT, smart city
- **URLLC**: Ultra Reliable Low Latency – Automation, healthcare

**Edge Computing in 5G**

**Definition**

- Brings **cloud capabilities closer to users** (near edge) to reduce **latency** and improve **QoS**.

**Applications**

- **Healthcare**
- **AR/VR/MR**
- **Tactile Internet**
- **IoT**
- **Smart Transportation**
- **Entertainment & Media**
- **Emergency Response**
- **Industry 4.0 (Factories of the future)**