



# **SUSTAINABILITY IN ENGINEERING DESIGN**

## **(24CV306B)**

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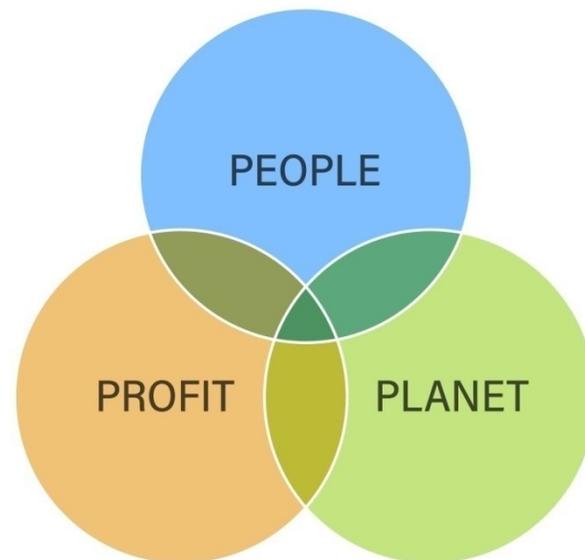
# Syllabus

## Module 4:

Sustainability complexity and design competences,  
Acquiring key competences - Workshop setting,  
Sustainable design and scientific research, Sustainable  
design and conventional design, Examples from engineering  
practices - sustainable design and construction practices in  
the built environment –GRIHA and LEED rating system

# Sustainability Complexity

- Sustainability introduces **multi-dimensional, interacting, uncertain, long-term and competing requirements** into engineering design.
- Therefore, the design process is no longer linear — it becomes a **complex, dynamic system**.



# Sustainability Complexity

## Dimensions of Sustainability Complexity

### **Multi-Dimensional:** Triple Bottom Line (TBL):

- **Environmental (Planet):** Minimizing pollution, reducing resource depletion, protecting ecosystems, and cutting emissions.
- **Social (People):** Ensuring equity, safety, health, community well-being, and fair labor practices.
- **Economic (Profit):** Maintaining profitability, ensuring long-term financial viability, and promoting economic growth.

# Sustainability Complexity

## Interacting

- The different requirements and components of a design **interact** in complex ways. Improving one area can negatively impact another.

## Example:

- A material chosen for its **environmental** benefit (e.g., being recyclable) might be significantly more **expensive** (negative economic impact) or less durable (negative long-term social/economic impact) than the conventional option.

# Sustainability Complexity

**Uncertain:** Sustainability are inherently **uncertain** and difficult to predict:

- **Future Regulations:** How will environmental laws change over the product's lifespan?
- **Climate Impacts:** What specific climate changes will affect the product or its supply chain?
- **Consumer Behavior:** How will the market's demand for "green" products evolve?
- **Resource Availability:** The long-term availability and cost of finite or critical materials.

# Sustainability Complexity

## Long-Term

- Sustainability requires engineers to adopt a **life-cycle perspective**, looking far beyond the initial manufacturing and use phase to consider:
- **Cradle-to-Grave/Cradle-to-Cradle:** The impacts from raw material extraction, production, distribution, use, and end-of-life disposal or recycling.
- The design decisions made today will have **environmental, social, and economic consequences decades** into the future.

# Sustainability Complexity

## Competing (Trade-Offs)

- Often, the goals are in direct **competition** with each other, forcing difficult **trade-offs** that require nuanced decision-making:
  - **Cost vs. Eco-Friendliness:**

Designing for lower environmental impact (e.g., using new, expensive bio-materials) often increases the initial capital cost (**economic vs. environmental**).
  - **Efficiency vs. Local Impact:**

Constructing a massive, efficient renewable energy plant may displace a local community (**environmental/economic vs. social**).

# Sustainable Design Competences

## Cognitive & Analytical Competences (Knowing)

- These skills involve understanding the complexity of sustainability challenges.

## Systems Thinking Competence

- **The Skill:** The ability to see the product or project not in isolation, but as a component of a larger, interconnected **socio-ecological-technical system**.
- **Application:** Identifying **feedback loops, cascading effects, and trade-offs** across multiple scales (local to global) and domains (society, environment, economy). This is crucial for avoiding problem-shifting (e.g., solving a waste problem by increasing energy use).

# Sustainable Design Competences

## Life Cycle Thinking & Assessment (LCA)

- **The Skill:** The capacity to evaluate the environmental and social impacts of a product or service across its **entire lifespan**, from raw material extraction ("cradle") to end-of-life disposal or recycling ("grave" or "cradle").
- **Application:** Quantifying impacts (e.g., carbon footprint, water use, toxicity) at each stage to make informed material selections and design decisions, prioritizing impact reduction where it is most severe.

# Sustainable Design Competences

## Normative & Ethical Thinking (Values)

- **The Skill:** The ability to understand, map, and reconcile **conflicting values** (e.g., economic growth vs. ecosystem protection) and to apply principles of **justice, equity, and responsibility** (e.g., intergenerational equity).
- **Application:** Identifying ethical red flags, defining **sustainability principles/goals** for a project, and using **multi-criteria assessment methods** to balance competing needs.

# Sustainable Design Competences

## Strategic & Action-Oriented Competences (Doing)

- These are the skills needed to create and implement solutions for a sustainable future.

## Futures Thinking

- **The Skill:** The capacity to **envision and articulate desirable future states** and to anticipate how current decisions may create or solve future sustainability problems.
- **Application:** Developing multiple **scenarios** (plausible, possible, and desirable) to test the robustness of a design against future trends like climate change, resource scarcity, and policy changes.

# Sustainable Design Competences

## Strategic Design & Intervention

- **The Skill:** The ability to design and implement **transformational actions** and transition strategies that move the current system toward the desired future state.
- **Application:** Focusing on **regenerative** and **circular economy** strategies (e.g., designing for durability, repair, disassembly, and reuse) rather than just incremental optimization. This includes designing for **dematerialization** (using less material).

# Sustainable Design Competences

## Technical Expertise in Sustainable Solutions

- **The Skill:** Domain-specific knowledge in areas like **sustainable materials** (recycled, renewable, low-impact), **renewable energy systems**, and **resource efficiency** (energy and water).
- **Application:** Applying DfMA (Design for Manufacturing and Assembly) principles with a sustainability lens, such as selecting materials with low embodied energy and high recyclability.

# Sustainable Design Competences

## Collaborative & Transformational Competences

### (The "Working With Others")

- Sustainability challenges require working across disciplinary boundaries and engaging diverse groups.

## Interpersonal & Collaboration

- **The Skill:** The ability to **collaborate effectively** in **multidisciplinary teams** (e.g., engineers, social scientists, economists, policymakers) and to facilitate **stakeholder participation**.
- **Application:** Negotiating trade-offs and building consensus among groups with competing interests (e.g., industry, local community, and environmental NGOs) to create shared, viable solutions.

# Sustainable Design Competences

## Leadership & Change Management

- **The Skill:** The capacity to act as a **leader for change**, influencing peers, organizations, and the supply chain to adopt more sustainable practices.
- **Application:** Applying responsible judgment, going beyond minimum compliance, and actively striving for **regenerative outcomes** that restore and replenish natural and social systems.

## Acquiring key competences - Workshop setting

- A **workshop setting** is highly effective for acquiring sustainable design competences because it leverages **active learning methodologies** to foster skills that are inherently relational, complex, and action-oriented. Unlike passive lectures, workshops allow participants to immediately apply new knowledge, practice collaboration, and confront real-world trade-offs.
- The acquisition of sustainable design competences in a workshop typically focuses on three key processes: **Experiential Learning, Collaboration, and Reflection.**



# Acquiring key competences - Workshop setting

## I. Developing Cognitive & Analytical Competences

### I. Systems Thinking

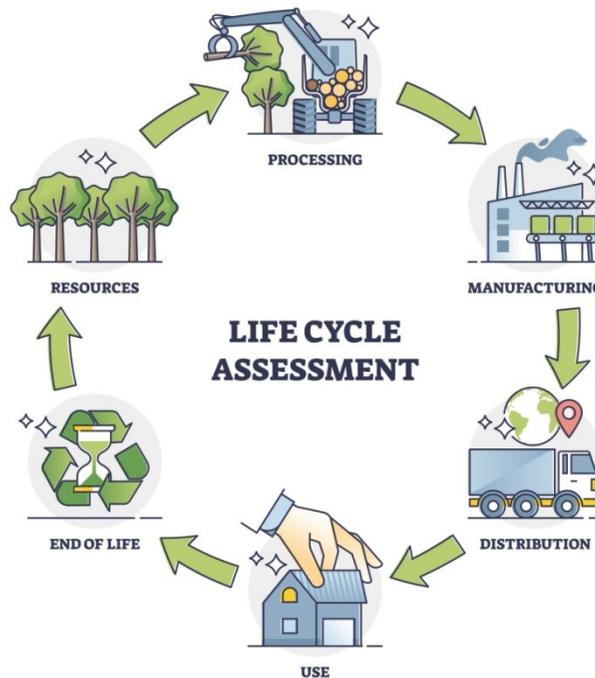
- **Workshop Activity: Causal Loop Diagramming:** Participants are given a problem statement (e.g., "high water consumption in a manufacturing plant"). They identify all interacting variables (e.g., product volume, cooling systems, local water stress, regulations) and map them using arrows to show **cause-and-effect relationships** and **feedback loops** (both reinforcing and balancing).
- **Key Outcome:** Shifts participants from linear, siloed thinking to a **holistic view** where they understand how a change in one area causes ripple effects throughout the system.

# Acquiring key competences - Workshop setting

## I. Developing Cognitive & Analytical Competences

## 2. Life Cycle Thinking & Assessment (LCA)

- **Workshop Activity: Product Journey Mapping:** Teams choose a common product (e.g., a plastic bottle or a smartphone) and visually map its entire journey:



**Raw Material Extraction**

to

**Manufacturing**

to

**Distribution**

to

**Use**

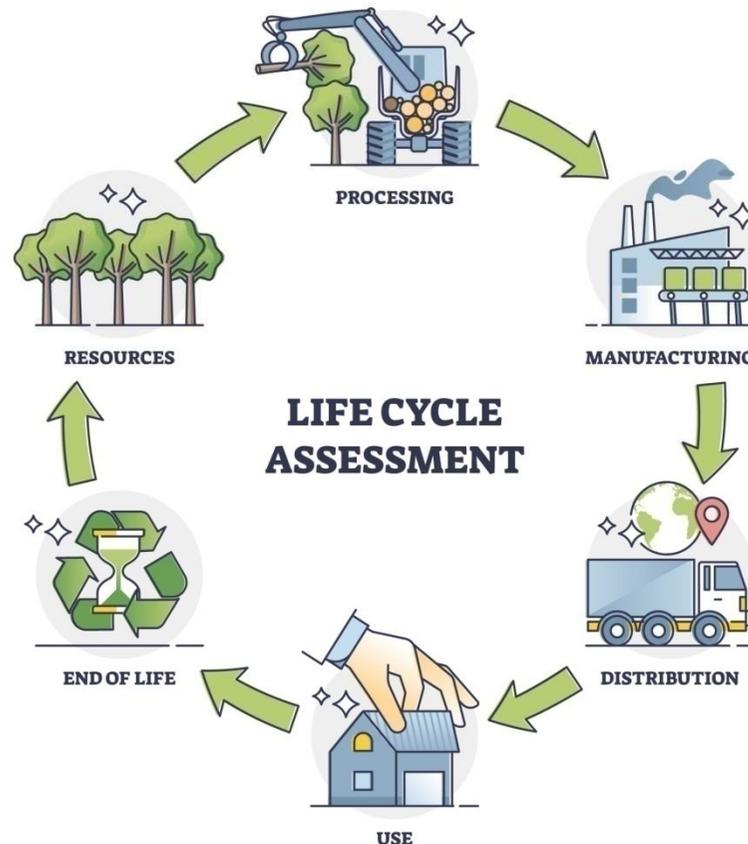
at last

**End-of-Life.**

# Acquiring key competences - Workshop setting

## I. Developing Cognitive & Analytical Competences

## 2. Life Cycle Thinking & Assessment (LCA)



**Raw Material Extraction**  
to  
**Manufacturing**  
to  
**Distribution**  
to  
**Use**  
at last  
**End-of-Life.**

**Key Outcome:** Develops the ability to identify "hotspots" of environmental impact (e.g., material sourcing vs. energy-in-use) and teaches the principles of "cradle-to-cradle" design.

# Acquiring key competences - Workshop setting

## II. Practicing Strategic & Action-Oriented Competences

- Workshops provide a low-risk environment for practicing **future-oriented** and **strategic** design actions.

### 3. Futures Thinking (Anticipatory)

- **Workshop Activity: Scenario Planning/Futures Wheel:** Teams are presented with a major trend or event (e.g., "Water tariffs increase 500% in 5 years" or "Ban on single-use plastics is globally adopted"). They use the Futures Wheel tool to brainstorm **first-, second-, and third-order consequences** for their design project, forcing them to design for resilience and future robustness.
- **Key Outcome:** Moves thinking beyond immediate constraints to **anticipate** and proactively design for different possible and desirable futures.

# Acquiring key competences - Workshop setting

## II. Practicing Strategic & Action-Oriented Competences

### 4. Strategic Design & Intervention

- **Workshop Activity: Circular Economy Ideation (The 9 R's):** Using a current product design, teams are tasked with applying circular strategies like **Rethink, Reduce, Repair, Refurbish, and Recycle** to generate concrete ideas for extending the product's lifespan and reducing waste.
- **Key Outcome:** Teaches concrete, actionable strategies for designing regenerative systems rather than just minimizing negative impacts.

# Acquiring key competences - Workshop setting

## III. Fostering Collaborative & Transformational

**Competences:** Sustainability is a collective challenge, and workshops are ideal for building interpersonal skills.

### 5. Interpersonal & Ethical Competence

- **Workshop Activity: Stakeholder Role-Playing/Viewpoints on the Line:** Teams receive roles (e.g., CEO, local resident, environmental NGO, engineer) in a controversial project. They must present their perspective and then collaboratively negotiate a solution that balances the **Triple Bottom Line (People, Planet, Profit)**.
- **Key Outcome:** Fosters **empathy** and the ability to reconcile **competing values** and interests, which is vital for real-world project approval and success.

# Acquiring key competences - Workshop setting

## III. Fostering Collaborative & Transformational Competences:

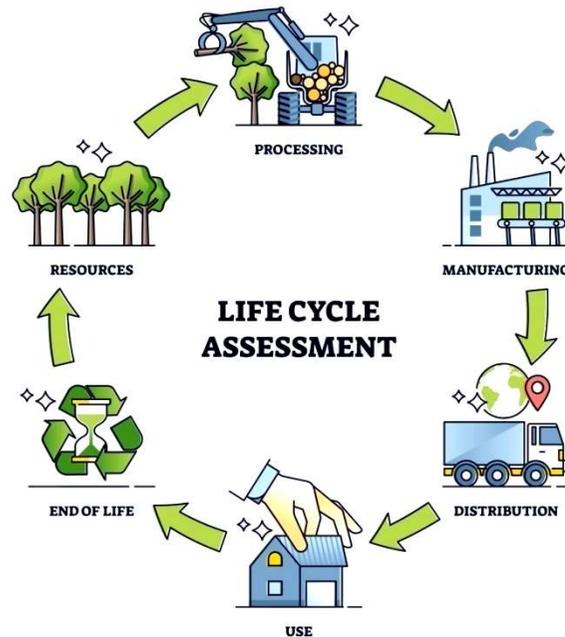
### 6. Leadership & Change Management

- **Workshop Activity: Action Planning Canvas:** Teams select their best sustainable design idea and translate it into a structured implementation plan, defining **goals, required resources, key performance indicators (KPIs)**, and a **communication strategy** for internal and external stakeholders.
- **Key Outcome:** Transforms an idea into a practical, persuasive plan, building confidence in **leading change** within an organization.

# Sustainable design and scientific research

## The Core Role of Scientific Research

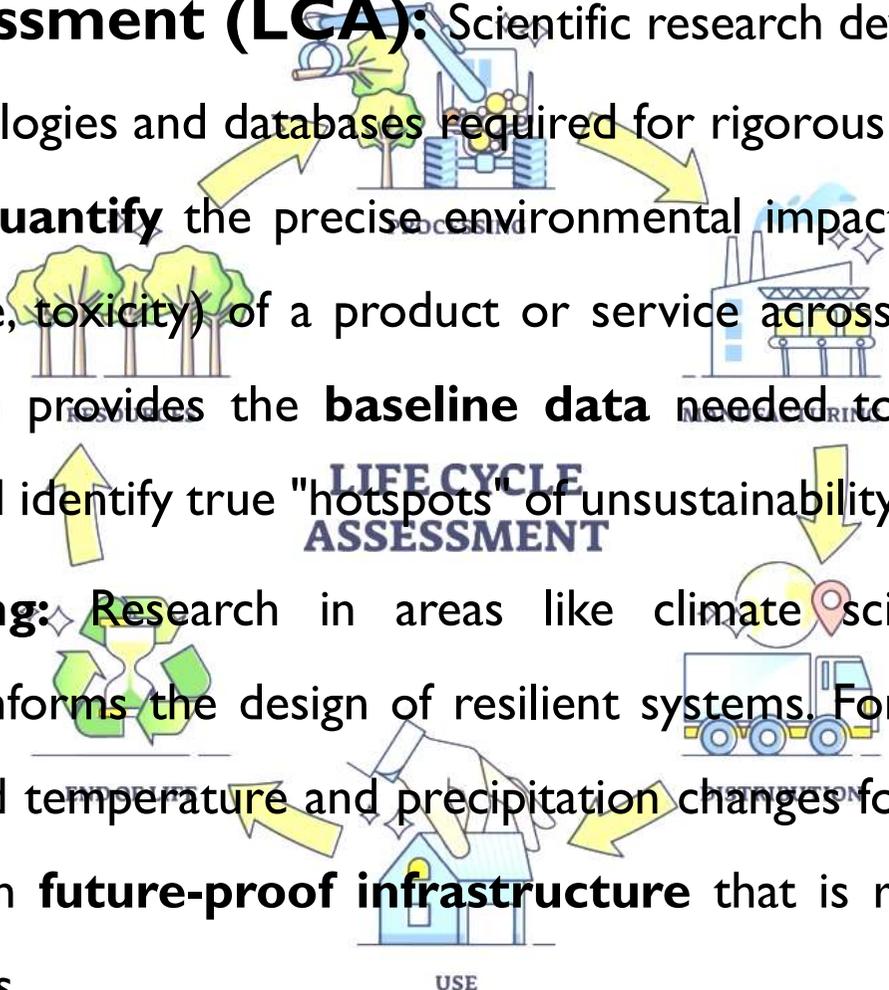
- Scientific research serves as the **source of truth** and the **wellspring of innovation** for sustainable design, directly addressing the multi-dimensional and uncertain nature of sustainability.



# Sustainable design and scientific research

## I. Quantification and Benchmarking

**I. Life Cycle Assessment (LCA):** Scientific research develops and validates the methodologies and databases required for rigorous LCA. This allows designers to **quantify** the precise environmental impacts (carbon footprint, water usage, toxicity) of a product or service across its entire lifespan. The research provides the **baseline data** needed to compare design alternatives and identify true "hotspots" of unsustainability.



- **Predictive Modeling:** Research in areas like climate science and ecological modeling informs the design of resilient systems. For example, knowing the predicted temperature and precipitation changes for a region helps engineers design **future-proof infrastructure** that is resilient to climate change impacts.

# Sustainable design and scientific research

## 1. Quantification and Benchmarking

## 2. Technological Innovation

- **Sustainable Materials Science:** Research is constantly discovering, engineering, and testing new materials. This includes:
  - **Self-Healing Materials:** Concrete or polymers that automatically repair cracks, significantly extending product and infrastructure lifespan.
  - **Low-Carbon Alternatives:** Developing cement alternatives using materials like **seaweed** or industrial byproducts to drastically cut carbon emissions.



# Sustainable design and scientific research

## 1. Quantification and Benchmarking

## 2. Technological Innovation

- **Sustainable Materials Science:** Research is constantly discovering, engineering, and testing new materials. This includes:
  - **Bio-inspired Materials (Biomimicry):** Creating materials that replicate natural functions, like self-cleaning surfaces (lotus effect) or ultra-strong, lightweight structures (bone structure).
- **Clean Energy Systems:** Research into **Green Hydrogen** production, **Solid-State Batteries**, and more efficient **Carbon Capture and Storage (CCS)** provides the essential technologies for decarbonizing operations and power consumption in design solutions.

# Sustainable design and scientific research

## II. Informing Sustainable Design Competences

- Research doesn't just provide technology; it directly shapes the cognitive and strategic competences required for designers.

| Competence       | How Scientific Research Contributes  |
|------------------|--|
| Systems Thinking | Research on Socio-Ecological Systems (SES) provides frameworks for understanding how human technology interacts with social structures and the environment, preventing problem-shifting. |
| Futures Thinking | Scenario planning and risk modeling from climate and resource science provide the necessary data and projections to create robust, anticipatory design strategies.                       |

# Sustainable design and scientific research

## II. Informing Sustainable Design Competences

| Competence          | How Scientific Research Contributes   |
|---------------------|---|
| Strategic Design    | Empirical research on the effectiveness of circular economy models and product service systems (PSS) guides designers on how to transition to regenerative models.                  |
| Normative & Ethical | Social science research assesses the social impacts and equity concerns of technologies (e.g., job displacement, resource access), ensuring designs promote fair and just outcomes. |

# Sustainable design and scientific research

## III. Key Scientific Breakthroughs Driving Design

- Recent scientific and engineering research breakthroughs are directly enabling new sustainable design paradigms:
- **AI-Powered Design Optimization:** Artificial Intelligence tools like **generative design software** can rapidly simulate and optimize millions of design iterations to find the **most material-efficient and lowest-impact solutions** that human designers might miss.

# Sustainable design and scientific research

## III. Key Scientific Breakthroughs Driving Design

- **Advanced Recycling/Resource Recovery:** Scientific discoveries, such as a low-energy method to recycle notoriously durable plastics like **Teflon®**, enable engineers to design products that rely on closed-loop material streams with confidence.
- **Precision Agriculture & Water Tech:** Research in **CRISPR-edited crops** that make their own fertilizer or advancements in **hydroponics/vertical farming** allow designers to create highly resource-efficient food systems that minimize land and water use, integrating food production into urban environments.

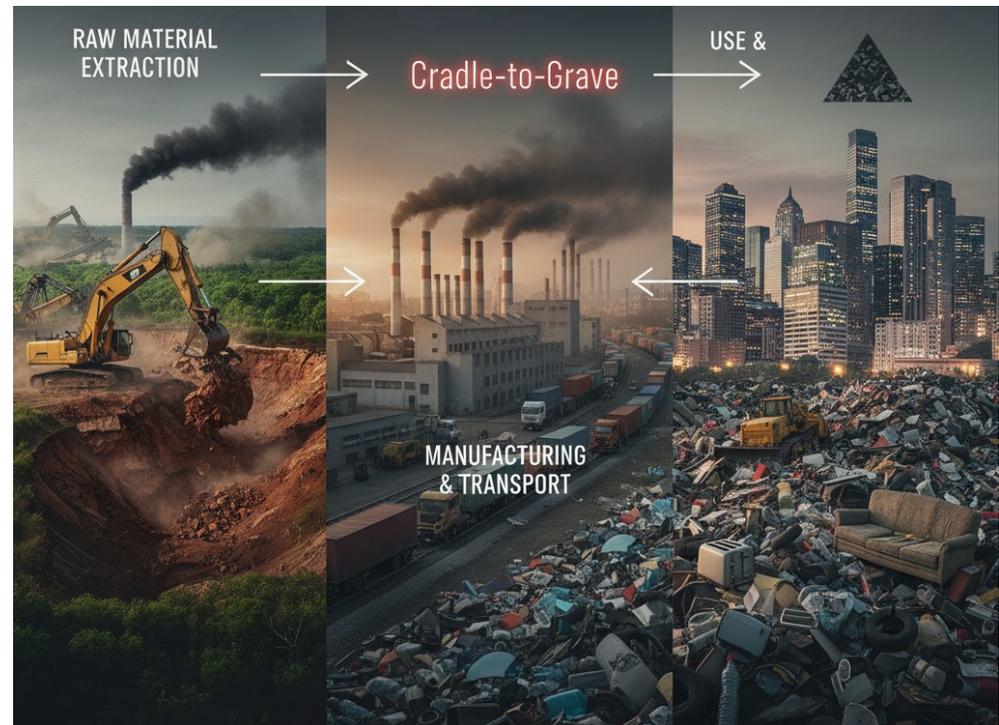
# Sustainable design and conventional design

## Conventional Design: Linear & Anthropocentric

- **Focus:** Primarily on human needs, aesthetics, and immediate economic gain. Nature is often seen as a resource to be extracted and a sink for waste.

- **Process:**

A straightforward, linear progression from resource extraction to disposal.



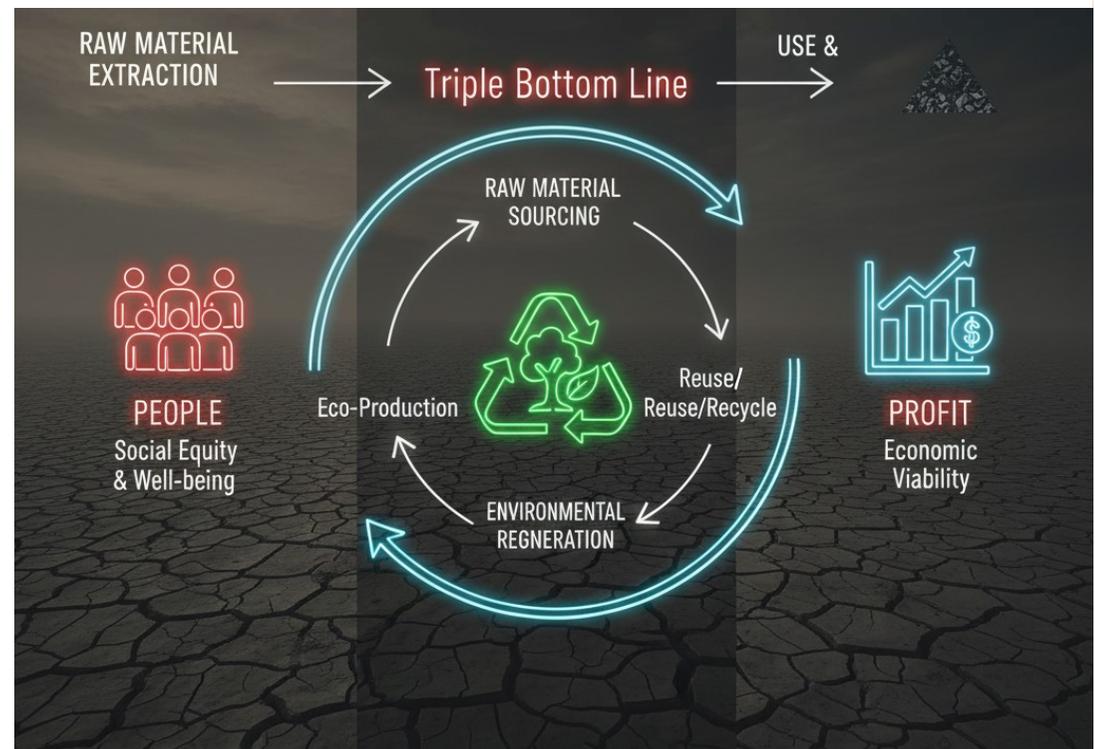
# Sustainable design and conventional design

## Sustainable Design: Circular & Holistic (Triple Bottom Line)

- **Focus:** Balances **People, Planet, and Profit**. Recognizes that human well-being and economic viability depend on a healthy environment.

- **Process:**

A circular, iterative approach aiming to eliminate waste and regenerate resource



| Feature            | Conventional Design   | Sustainable Design<br>(Eco-Design / Green Design)  |
|--------------------|---|--|
| Primary Goal       | Optimization for Cost & Functionality. The main focus is meeting the required performance specifications at the lowest immediate upfront cost.      | Optimization for the Triple Bottom Line (TBL). The goal is to maximize performance while minimizing negative environmental and social impacts across the life cycle, aiming for long-term value. |
| Economic View      | Initial Cost Focus. Prioritizes low material/manufacturing costs today, often leading to cheaper, less durable materials.                           | Life-Cycle Costing (LCC). Considers all costs over the product's lifespan (maintenance, energy, disposal/recycling), often leading to higher upfront but lower long-term costs.                  |
| Environmental View | End-of-Pipe Regulation. Focuses on meeting minimum legal standards for pollution and waste treatment at the point of release (at the factory gate). | Cradle-to-Cradle/Regenerative. Aims to design out waste entirely, use materials that can be safely recycled or composted, and contribute positively to natural systems.                          |

# Sustainable design and conventional design

## Design Scope and Methodology

### I. Time Horizon

- **Conventional Design:** Typically a **linear process** ("**Cradle-to-Grave**"), where the designer's responsibility ends when the product is sold or when it leaves the factory.<sup>1</sup> Disposal is the user's problem.
- **Sustainable Design:** An **iterative process** using **Life Cycle Thinking** (LCT). The designer is responsible for the product from "**Cradle-to-Cradle**" (raw material extraction to manufacturing to use to reuse/recycling).

# Sustainable design and conventional design

## Design Scope and Methodology

### 2. Materials Selection

- **Conventional Design:** Focuses on performance, availability, and low cost. Material origins and end-of-life status (e.g., toxicity, recyclability) are secondary concerns.
- **Sustainable Design:** Prioritizes **low-embodied energy** materials (materials with low energy used in their production), **renewable/recycled content**, **non-toxicity** (e.g., low-VOC paints), and **local sourcing** to reduce transportation impact.

# Sustainable design and conventional design

## Design Scope and Methodology

### 3. Energy Use

- **Conventional Design:** Focuses on meeting operational needs with the cheapest available energy source, with little regard for energy efficiency beyond regulatory standards.
- **Sustainable Design:** Prioritizes **drastic energy reduction** (e.g., through passive design, excellent insulation) and sourcing from **renewable energy** (e.g., integrating solar PV, efficient HVAC systems).<sup>4</sup> It targets both **operational carbon** (energy used during use) and **embodied carbon** (energy used to make the materials).

# Sustainable design and conventional design

## Design Scope and Methodology

### 4. Waste

- **Conventional Design:** Waste is seen as an unfortunate byproduct of the process, managed through disposal (landfill) or minimal recycling efforts.
- **Sustainable Design: Waste is seen as a design flaw.** Strategies include **Design for Disassembly (DfD)**, using mono-materials to facilitate easier recycling, and promoting **durability** and **repairability** to extend product life.

# Sustainable design and conventional design

| <b>Design Element</b> | <b>Conventional Design</b>               | <b>Sustainable Design</b>                                    |
|-----------------------|--|--|
| Optimization Focus    | Function, Aesthetics, & Low Initial Cost | Triple Bottom Line (People, Planet, Profit)                  |
| Timeframe             | Short-Term (Production to Sale)          | Long-Term (Entire Life Cycle)                                |
| Process               | Linear ("Cradle-to-Grave")               | Circular ("Cradle-to-Cradle")                                |
| Key Metric            | Upfront Cost, Schedule Compliance        | Life-Cycle Cost (LCC), Carbon Footprint, Resource Efficiency |
| Risk View             | Technical & Financial Risk               | Technical, Financial, Environmental, & Social Risk           |

# Sustainable Environment

## Sustainable design and construction practices in the built environment –**GRIHA** and **LEED** rating system

- Green Building Rating Systems are comprehensive tools used in engineering practice to **quantify, measure, and validate** the sustainability performance of buildings throughout their life cycle.
- By setting specific benchmarks, they guide the design, construction, and operation of structures to reduce environmental impact and enhance human health.
- The two prominent examples discussed here are **GRIHA** (India's national system) and **LEED** (the globally dominant system).

# Sustainable Environment

## The Role of Green Building Rating Systems

- Green Building Rating Systems (GBRS) serve as quantifiable frameworks that assess the environmental, social, and economic performance of buildings. They move sustainable design from abstract principles to measurable engineering standards, ensuring resource efficiency, occupant health, and minimized environmental impact across a building's entire lifecycle.

## Common Objectives of GBRS:

- **Reduce Resource Consumption:** Minimize energy, water, and material use.
- **Improve Health:** Enhance Indoor Environmental Quality (IEQ) for occupants.
- **Minimize Ecological Damage:** Promote sustainable site planning and protect biodiversity.

# Sustainable Environment

## GRIHA

### (Green Rating for Integrated Habitat Assessment)

- GRIHA is **India's national green building rating system** developed by TERI (The Energy and Resources Institute) and endorsed by the Ministry of New and Renewable Energy (MNRE), Government of India.
- GRIHA, meaning "Abode" in Sanskrit, is India's national rating system, developed by TERI and endorsed by the Government of India. It is specifically designed to address the socio-economic and climatic conditions unique to the Indian subcontinent.

# Sustainable Environment

## GRIHA

- **Indian Ethos:** GRIHA prioritizes indigenous materials, passive solar techniques, and site-specific resource management, aligning with India's diverse climatic zones (composite, hot-dry, warm-humid, cold).
- **Mandatory Criteria:** GRIHA has several mandatory requirements that must be met to even qualify for certification, ensuring a baseline of sustainability.
- **Life Cycle Assessment (LCA):** The system deeply integrates LCA principles, particularly in its focus on the embodied energy and Global Warming Potential (GWP) of building materials.

# Sustainable Environment

## GRIHA: Max 100 Points

| <b>Category (Points)</b>                | <b>Key Sustainable Design Practices and Requirements</b>   |
|---|--|
| I. Sustainable Site Planning (8 points) | Low Impact Design (LID): Minimizing impervious surfaces and maximizing green infrastructure. UHIE Mitigation: Using high-reflectance materials (SRI values) on roofs and paved surfaces.   |
| II. Construction Management (9 points)  | Pollution Control: Implementation of stringent measures for air and soil pollution control on site. Topsoil Preservation: Protecting and reusing excavated topsoil. Worker Welfare: Mandatory safety, sanitation, and dedicated facilities for construction labor.                     |
| III. Energy Efficiency (20 points)      | Energy Optimization: Optimizing the building envelope (walls, roof, windows) for maximum thermal comfort and minimum mechanical heating/cooling demand (passive design). Renewable Energy (RE): Utilization of on-site solar, wind, or other renewable energy to offset building load. |

# Sustainable Environment

| Category (Points)                       | Key Sustainable Design Practices and Requirements  |
|---|--|
| IV. Occupant Comfort (12 points)        | Thermal & Visual Comfort: Use of daylight and ensuring prescribed air changes per hour (ACH). IAQ: Use of low-VOC (Volatile Organic Compound) paints, sealants, and adhesives in interiors.  |
| V. Water Management (17 points)         | Demand Reduction: Installing low-flow plumbing fixtures (toilets, faucets) to conserve potable water. Wastewater Treatment: Mandatory on-site treatment (e.g., Sewage Treatment Plants - STP) and reuse of treated water for flushing, irrigation, and cooling towers. |
| VI. Sustainable Materials (14 points)   | Alternative Materials: Using materials with high recycled content (e.g., fly ash bricks) and those utilizing local/regional resources. Embodied Energy Reduction: Mandatory requirement to reduce GWP/Embodied Energy of structural materials through LCA.             |
| VII. Monitoring & Validation (7 points) | Smart Metering: Mandatory installation of smart meters for continuous monitoring of energy and water consumption post-occupancy to ensure performance gaps are minimized.  |

# Sustainable Environment

## GRIHA

### A. Core Focus and Goals

- **Contextual Relevance:** GRIHA is tailored to India's diverse climate zones, resources, and construction practices, aiming to minimize a building's ecological impact within **nationally acceptable benchmarks**.
- **Life Cycle Approach:** It evaluates the environmental performance of a building **holistically over its entire life cycle**, from construction to demolition.
- **Quantification:** It quantifies aspects like energy consumption, waste generation, and renewable energy adoption to ensure that "what gets measured, gets managed".

# Sustainable Environment

## GRIHA

### B. Key Rating Categories (Criteria)

- GRIHA assesses projects based on criteria divided into several categories, generally totaling **100 points** across criteria and 4 additional points for innovation.
- **Sustainable Site Planning:** Includes low-impact design, site selection, and measures to mitigate the Urban Heat Island Effect (UHIE).
- **Construction Management:** Focuses on air and soil pollution control, preservation of topsoil/landscape, and worker safety/sanitation.

# Sustainable Environment

## GRIHA

### B. Key Rating Categories (Criteria)

- **Energy Efficiency:** Optimizing building design to reduce conventional energy demand and utilizing **Renewable Energy (RE)** sources.
- **Water Management:** Reduction in water demand, wastewater treatment, rainwater management, and water quality.
- **Sustainable Building Materials:** Promoting the use of alternative materials (e.g., waste materials like fly ash), and reducing the **Global Warming Potential (GWP)** and **Embodied Energy** through Life Cycle Assessment (LCA).

# Sustainable Environment

## GRIHA

### B. Key Rating Categories (Criteria)

- **Occupant Comfort and Well-being:** Ensuring good Indoor Air Quality (IAQ), visual, thermal, and acoustic comfort.
- **Performance Monitoring:** Includes commissioning and smart metering/monitoring for ongoing performance validation.

# Sustainable Environment

## GRIHA

### C. GRIHA Certification Levels

- GRIHA uses a **Star Rating system** based on the percentage of total points achieved.

| Rating  | Points Achieved   |
|---------|-------------------|
| 1 Star  | 25-40 points      |
| 2 Stars | 41-55 points      |
| 3 Stars | 56-70 points      |
| 4 Stars | 71-85 points      |
| 5 Stars | 86 or more points |

# Sustainable Environment

## LEED

### (Leadership in Energy and Environmental Design)

- LEED is an **internationally recognized** green building certification system developed by the **U.S. Green Building Council (USGBC)**. It provides a comprehensive framework for designing, constructing, and operating high-performance green buildings



# Sustainable Environment

## LEED

- **Global Benchmarks:** LEED relies on established international standards (like ASHRAE, EPA, etc.) to set quantifiable benchmarks for building performance.
- **Market Transformation:** By creating demand for green materials and professional services (LEED APs), it has successfully driven the entire construction industry toward sustainable practices.
- **Performance-Based:** Certification is awarded based on the total number of points achieved, offering flexibility in which credits a project pursues.

# Sustainable Environment

## LEED:

LEED uses a **100-base point system** with additional points available for Innovation and Regional Priority (up to 110 total points).

| <b>Category<br/>(Potential<br/>Points)</b> | <b>Key Sustainable Design Practices and Requirements</b>   |
|--|--|
| Integrative Process (1 point)              | Conducting early-stage energy and water modeling/analysis to inform design decisions and set performance targets.  |
| Location and Transportation (16 points)    | Connectivity: Selecting sites near diverse uses, public transit, and community resources. Vehicle Use Reduction: Providing preferred parking for carpools, electric vehicles, and ample bicycle storage. |
| Sustainable Sites (11 points)              | Site Development: Protecting existing natural habitat and restoring degraded areas. Stormwater Management: Implementing green infrastructure like bioswales and pervious pavement to manage runoff.      |

| <b>Category<br/>(Potential<br/>Points)</b>        | <b>Key Sustainable Design Practices and Requirements</b>   |
|---|--|
| Water Efficiency<br>(11 points)                   | Water Use Reduction: Mandatory prerequisites for reduction. Credits for reducing potable water consumption through efficient irrigation, non-potable sources, and efficient indoor fixtures.   |
| Energy and<br>Atmosphere (33<br>points)           | Energy Performance: The largest category. Credits awarded for exceeding energy efficiency standards through design and systems optimization (HVAC, lighting, plug loads). On-site RE: Points for generating renewable power. Commissioning: Mandatory process to verify systems operate as intended. |
| Materials and<br>Resources (13<br>points)         | Waste Management: Diverting construction and demolition waste from landfills. Sourcing: Using materials with Environmental Product Declarations (EPDs), certified sustainable wood (FSC), or low embodied energy.  |
| Indoor<br>Environmental<br>Quality (16<br>points) | Acoustics & Lighting: Controlling noise levels and maximizing daylight/views. IAQ: Mechanical ventilation monitoring and use of low-emitting (low-VOC) interior materials.   |
| Innovation &<br>Regional Priority<br>(10 points)  | Recognizing exemplary performance in existing credits or innovative strategies not covered elsewhere.  |

# Sustainable Environment

## LEED

### A. Core Focus and Goals

- **Global Standard:** LEED is the most widely used system globally, adopted in over 160 countries.
- **Holistic Approach:** It aims to produce buildings that are healthy, highly efficient, and save carbon and money.
- **Impact Areas:** LEED-certified buildings have been shown to reduce CO<sub>2</sub> emissions by an average of 34% and energy consumption by 25% compared to standard buildings.

# Sustainable Environment

## LEED

**B. Key Credit Categories:** LEED uses a **point-based system** where projects earn credits across several categories to reach certification.

- **Integrative Process (IP):** Encourages early collaboration among project teams to optimize energy and water systems.
- **Location and Transportation (LT):** Promotes site selection near existing infrastructure, access to public transit, and reduced vehicle reliance.
- **Sustainable Sites (SS):** Focuses on minimizing impact on ecosystems, reducing stormwater runoff, and controlling light pollution.

# Sustainable Environment

## LEED

### B. Key Credit Categories

- **Water Efficiency (WE):** Optimizing indoor and outdoor water use through efficient fixtures, use of recycled water, and smart landscaping.
- **Energy and Atmosphere (EA):** The most heavily weighted category, emphasizing energy performance, commissioning, and use of renewable energy.
- **Materials and Resources (MR):** Encourages the use of sustainable, healthy, and regional materials, and the reduction of construction waste. points).

# Sustainable Environment

## LEED

### B. Key Credit Categories

- **Indoor Environmental Quality (IEQ):** Prioritizes thermal comfort, daylighting, access to views, and good Indoor Air Quality (IAQ) via ventilation and low-emitting materials.
- **Innovation (IN):** Awards points for strategies not covered by existing credits.
- **Regional Priority (RP):** Addresses environmental issues specific to the project's geographic area.

# Sustainable Environment

## LEED

### C. LEED Certification Levels

- LEED awards four ascending levels of certification based on the total points earned (out of a possible 110 points).

| Certification Level | Points Achieved     |
|---------------------|---------------------|
| Certified           | 40–49 points        |
| Silver              | 50–59 points        |
| Gold                | 60–79 points        |
| Platinum            | 80 points and above |

# Sustainable Environment

| Feature              | GRIHA (Green Rating for Integrated Habitat Assessment)  | LEED (Leadership in Energy and Environmental Design)  |
|----------------------|---|---|
| Origin / Development | India's national rating system, developed by TERI and endorsed by MNRE.   | International rating system, developed by the U.S. Green Building Council (USGBC).  |
| Context              | Climate and resource-specific to India, addressing regional ecology and natural resources.                                    | Global standard, with "Regional Priority" credits to address local issues.  |
| Emphasis             | More comprehensive and focuses heavily on site-specific issues, use of passive solar techniques, and cultural/social aspects. | Stronger focus on energy efficiency and water conservation through prescriptive measures and high-performance technologies. |
| Certification Levels | Star Rating (1-5 Stars).  | Tiered Levels (Certified, Silver, Gold, Platinum).  |
| Post-Construction    | Requires ongoing reporting of performance factors (energy, water, waste) to maintain certification.                           | Focuses more on design and construction, though separate ratings exist for existing buildings (O+M).                        |



# Sustainable Environment

## Sustainable design and construction practices in the built environment:

The integration of **Sustainable Design and Construction Practices** in the built environment represents a holistic approach to creating structures that are environmentally responsible, economically viable, and socially beneficial over their entire life cycle.

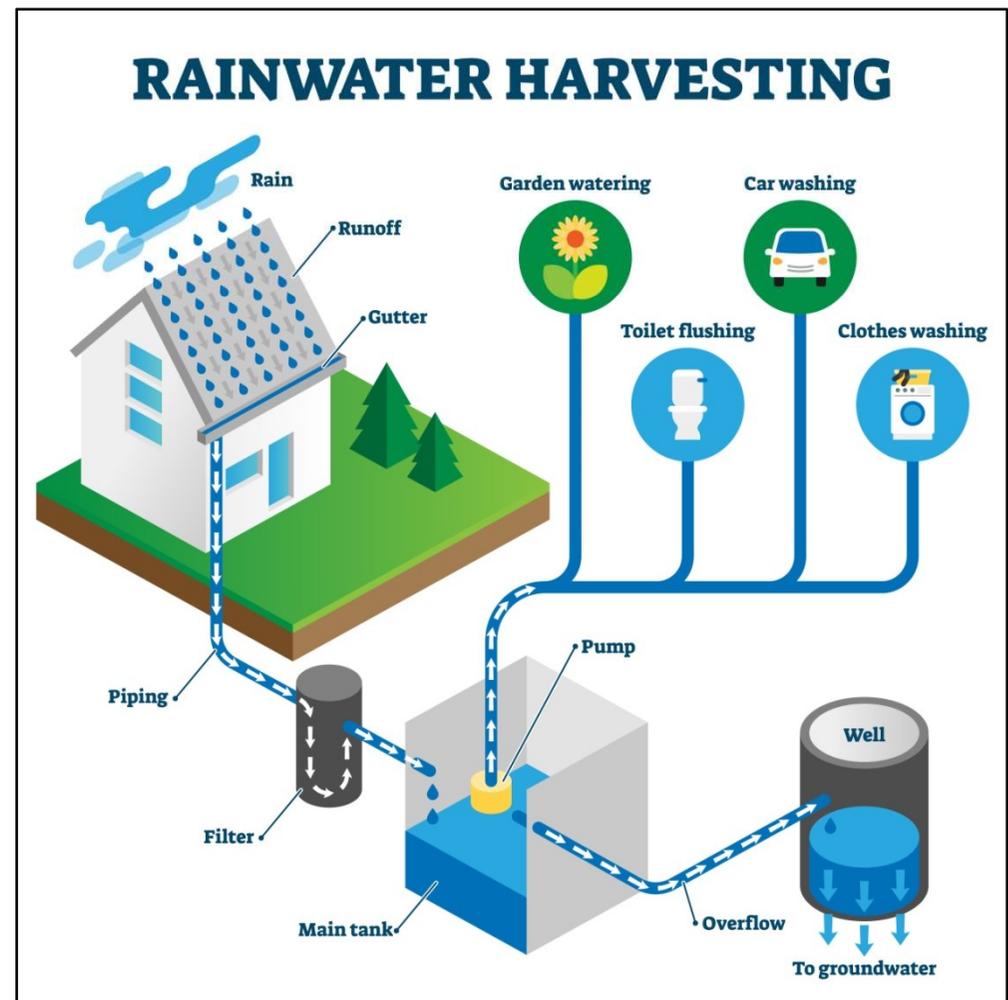
This approach, often guided by rigorous standards like **GRIHA** and **LEED**, shifts the focus from conventional "build and dispose" to a "cradle-to-cradle" model.

# Sustainable Environment

## Sustainable design and construction practices

### I. Fundamental Principles of Sustainable Design

- Sustainable design aims to drastically reduce the negative environmental impact of buildings by addressing five core areas:



# Sustainable Environment

## I. Fundamental Principles of Sustainable Design

### I. Resource Efficiency

- **Energy:** Minimizing the demand for conventional energy through **Passive Design** (e.g., maximizing daylight, optimizing orientation) and maximizing the use of **Renewable Energy** (e.g., solar panels). This includes reducing both **operational energy** (used during the building's life) and **embodied energy** (used to manufacture materials).
- **Water:** Reducing potable water consumption through efficient fixtures, **rainwater harvesting**, and treating/reusing gray and black water on-site

# Sustainable Environment

## I. Fundamental Principles of Sustainable Design

### 2. Sustainable Materials Selection

- Prioritizing materials that have **low embodied energy**, high **recycled content**, are **locally sourced** (to reduce transportation impact), and are **rapidly renewable** (e.g., bamboo, straw) .
- Avoiding materials with **Volatile Organic Compounds (VOCs)** or other toxins to ensure better indoor air quality (IAQ).

# Sustainable Environment

## I. Fundamental Principles of Sustainable Design

### 3. Site and Ecosystem Management

- **Site Selection:** Choosing sites near existing infrastructure and transit to reduce vehicle use.
- **Minimizing Disturbance:** Protecting existing green spaces, topsoil, and natural habitats during construction.
- **Stormwater Management:** Using **green infrastructure** (e.g., bioswales, rain gardens, permeable paving) to manage runoff and reduce pollution.

# Sustainable Environment

## I. Fundamental Principles of Sustainable Design

### 4. Occupant Health and Well-being (IEQ)

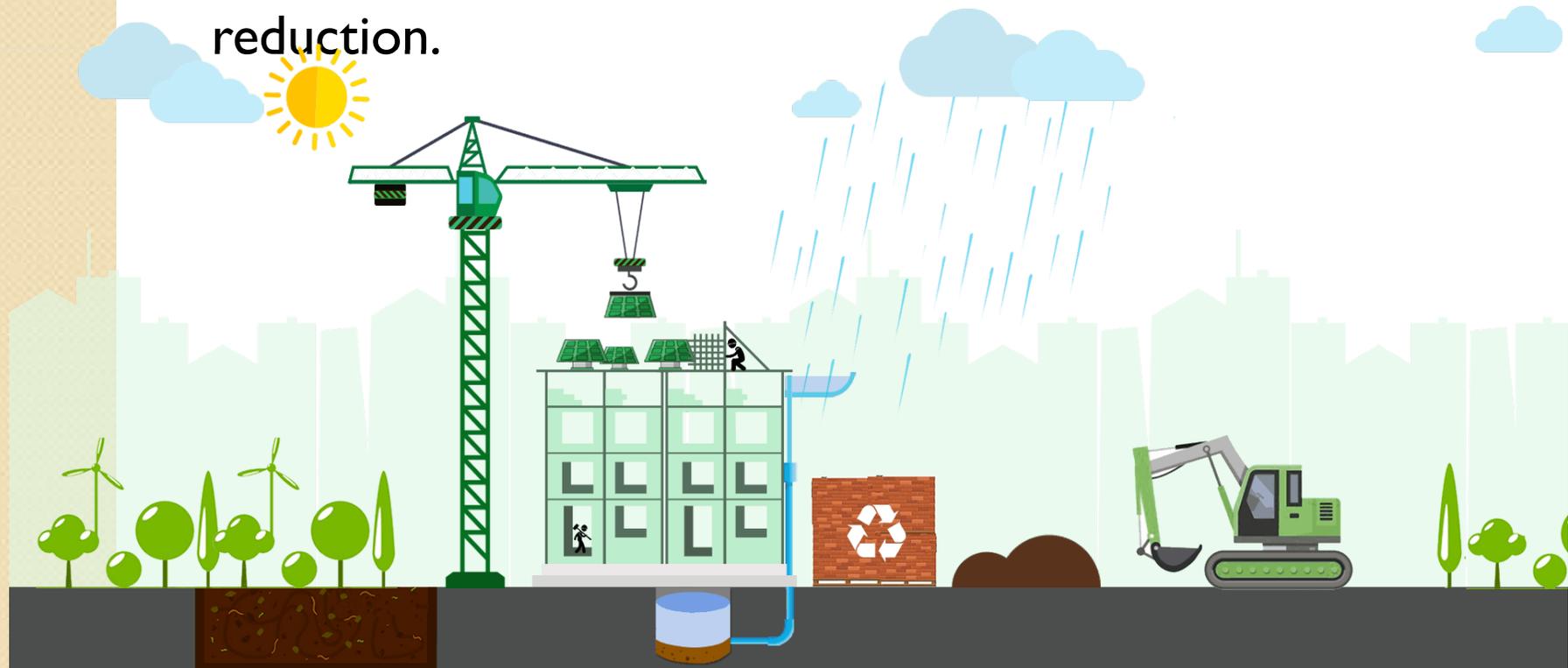
- **Indoor Air Quality (IAQ):** Ensuring proper ventilation, filtration, and using low-emitting materials.
- **Daylighting and Views:** Maximizing natural light and providing occupants with views of the outdoors to improve productivity and well-being.
- **Thermal Comfort:** Designing for consistent and comfortable indoor temperatures with minimal mechanical intervention.

# Sustainable Environment

## Sustainable design and construction practices

### II. Key Sustainable Construction Practices

- Sustainable practices extend the design principles into the construction phase itself, focusing on efficiency and waste reduction.



# Sustainable Environment

## II. Key Sustainable Construction Practices

### I. Construction Waste Management

- Implementing a plan to **reduce, reuse, and recycle construction and demolition (C&D) waste**, aiming to divert a high percentage of waste from landfills.
- **Deconstruction** (carefully taking a building apart to **reuse components**) rather than demolition.

# Sustainable Environment

## II. Key Sustainable Construction Practices

### 2. Erosion and Sediment Control

- Implementing strict measures (e.g., silt fences, sediment traps) to prevent soil erosion and control runoff, protecting nearby waterways and ecosystems during the construction period.

### 3. Integrated Project Delivery (IPD)

- Promoting early and close collaboration among all project stakeholders (architects, engineers, contractors, owners) to optimize the design from the start, avoiding costly changes and ensuring sustainable goals are met efficiently.

# Sustainable Environment

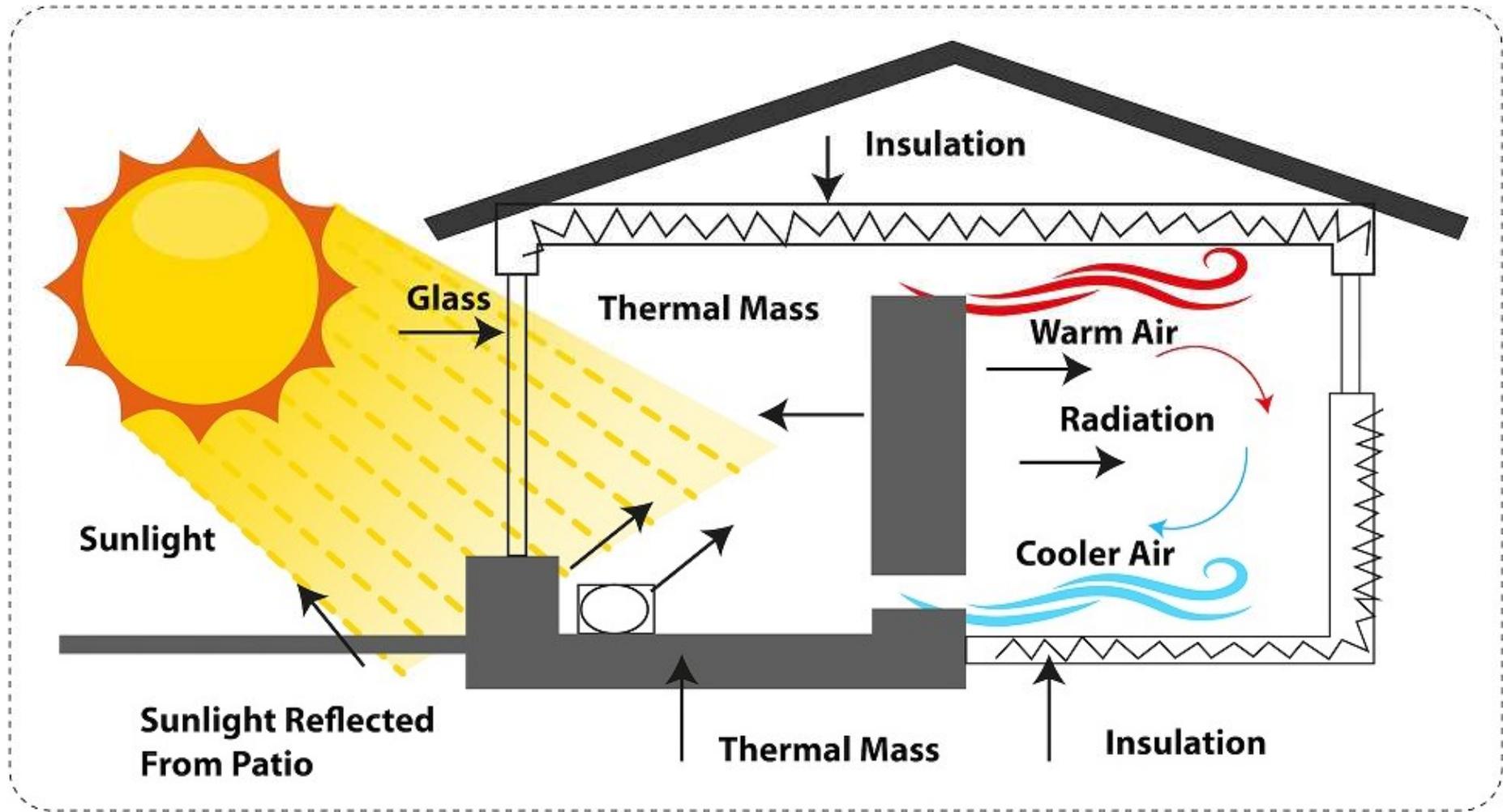
## Sustainable design and construction practices

### III. Validation Through Green Building Rating Systems

A. GRIHA (Green Rating for Integrated Habitat Assessment)

B. LEED (Leadership in Energy and Environmental Design)

# ENERGY-EFFICIENT DESIGNS AND MATERIALS





## ENERGY-EFFICIENT DESIGNS AND MATERIALS

- Energy efficiency in buildings means designing and operating buildings so that they use the **minimum possible energy** to provide the same level of comfort, functionality, and services, mainly by eliminating energy waste rather than simply restricting use.
- It focuses on **reducing energy demand for heating, cooling, lighting**, and equipment while maintaining thermal comfort and indoor environmental quality through both design and technology.



# ENERGY-EFFICIENT DESIGNS AND MATERIALS

## Energy efficiency in buildings

- Energy efficiency in buildings is the extent to which a building uses **less energy per unit floor area** than typical or benchmark buildings of the same type and under similar climatic conditions, **without compromising comfort, health, or functionality**.
- In practice, this means that the energy consumption per square metre of floor area is equal to or better than established benchmarks for that building category, indicating reduced wastage and better performance.



# ENERGY-EFFICIENT DESIGNS AND MATERIALS

## Energy efficiency in buildings

- Energy efficiency is no longer only “using less energy”; it now implies holistic and sustainable solutions that minimize environmental impact across the building’s life cycle. This includes efficient envelopes, systems, controls, and user behaviour, combined with clean energy sources like solar and wind power.

# ENERGY-EFFICIENT DESIGNS AND MATERIALS

## Need for energy efficiency in buildings

- Energy efficiency is needed because buildings today **consume more energy** than either the transport or industrial sectors in many countries, mainly for space conditioning, lighting, and appliances.
- Cutting this demand is essential to address climate change, as it **directly reduces greenhouse gas emissions from power plants that supply electricity and fuel for buildings.**



# ENERGY-EFFICIENT DESIGNS AND MATERIALS

## Need for energy efficiency in buildings

- **Environmental benefits:** Using less energy reduces the amount of fuel burned in power stations, which lowers emissions of carbon dioxide and other pollutants, improving air quality and slowing global warming.



# ENERGY-EFFICIENT DESIGNS AND MATERIALS

## Need for energy efficiency in buildings

- **Economic benefits:** Energy-efficient buildings **reduce operating costs**, with many studies showing 20–30 percent savings in energy bills for homeowners and businesses when efficiency measures are properly implemented.



# ENERGY-EFFICIENT DESIGNS AND MATERIALS



-  Climate Change & Pollution
-  Resource Depletion

**↓**  
**Unsustainable**



-  High Operating Costs
-  Rising Utility Bills  
Reduced Property Value

**↓**  
**Costly**

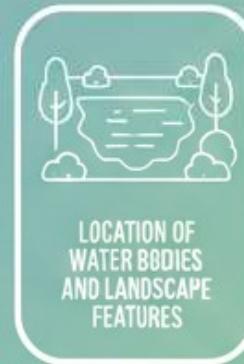


-  Discomfort & Health Issues
-  Stress & Financial Strain  
Poor Indoor Air Quality

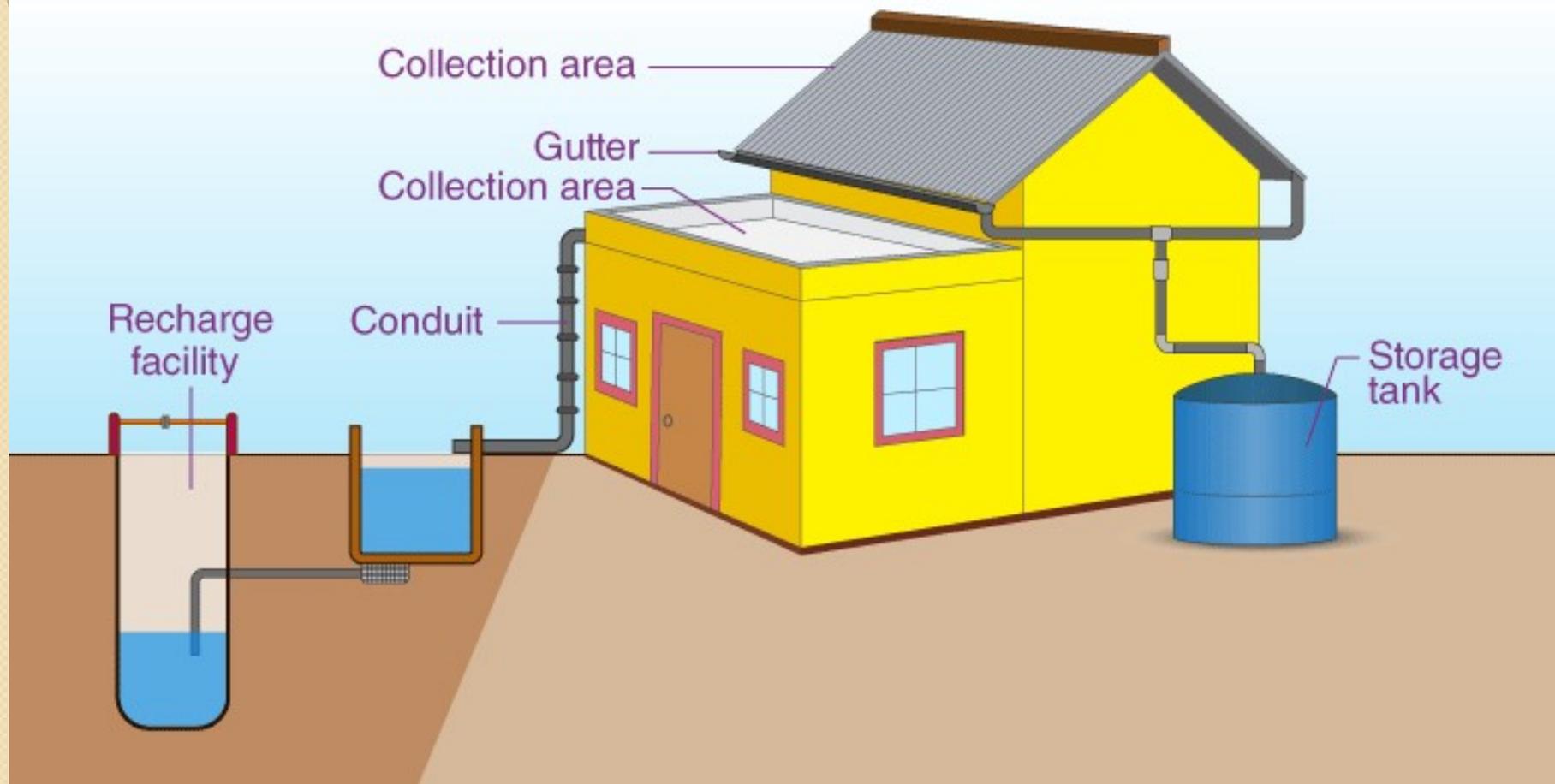
**↓**  
**Unhealthy**

# ENERGY-EFFICIENT DESIGNS AND MATERIALS

## DESIGN PRINCIPLES TO ACHIEVE ENERGY EFFICIENCY



# RAINWATER HARVESTING SYSTEMS



# RAINWATER HARVESTING SYSTEMS

Key system components:



CATCHMENT AREA



COARSE MESH AND GUTTERS



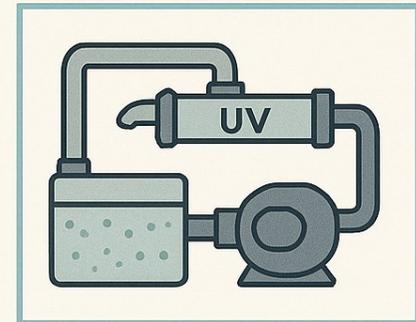
FIRST-FLUSH DIVERTER



PRE-FILTERS AND SEDIMENTATION



STORAGE TANKS



TREATMENT AND DISTRIBUTION

# RAINWATER HARVESTING SYSTEMS

**Key system components:** A complete rainwater harvesting system follows a logical sequence from collection to use:

- **Catchment area:** Primarily rooftops (RCC, GI sheets, or tiles) that directly receive rainfall; unpaved surfaces like lawns can supplement but require more filtration.
- **Coarse mesh and gutters:** Roof-level screens block leaves/debris; gutters (PVC, galvanized steel, or semi-circular channels) sized 10-15% oversize for peak storm flows transport water to downspouts.

# RAINWATER HARVESTING SYSTEMS

## Key system components:

- **First-flush diverter:** Discards initial 10-20 gallons (40-80L) of dirty "first flush" containing pollutants accumulated on roofs; simple PVC pipe or automatic diverters divert clean subsequent flow.
- **Pre-filters and sedimentation:** Leaf screens, sand/charcoal filters, or vortex filters remove finer particles before storage; multi-chamber filters (sand-aggregate-pebbles) handle large roofs.

# RAINWATER HARVESTING SYSTEMS

## Key system components:

- **Storage tanks:** Underground or elevated polyethylene/ferrocement tanks with floating intake for clean water extraction, overflow to recharge, and UV-resistant covers; sized based on rainfall, roof area, and demand.
- **Treatment and distribution:** Final filtration (microfiltration, UV, chlorination for potable use), pumps (if needed), and piping to end-uses; gravity-fed systems preferred for low energy.

**RAINWATER HARVESTING SYSTEMS**



# RAINWATER HARVESTING SYSTEMS

## Groundwater recharge methods

- Excess or untreated water recharges aquifers via

| Method                   | Description  | Suitability                             |
|--------------------------|--|---|
| Recharge pits/trenches   | Gravel-filled pits (1-2m deep) or trenches allow percolation | Shallow aquifers, sandy soils           |
| Percolation wells/shafts | Bored wells (3-5m deep) with filter media                    | Deeper aquifers, low-permeability soils |
| Permeable pavements      | Porous pavers direct runoff underground                      | Urban sites, parking areas              |

## Green roofs

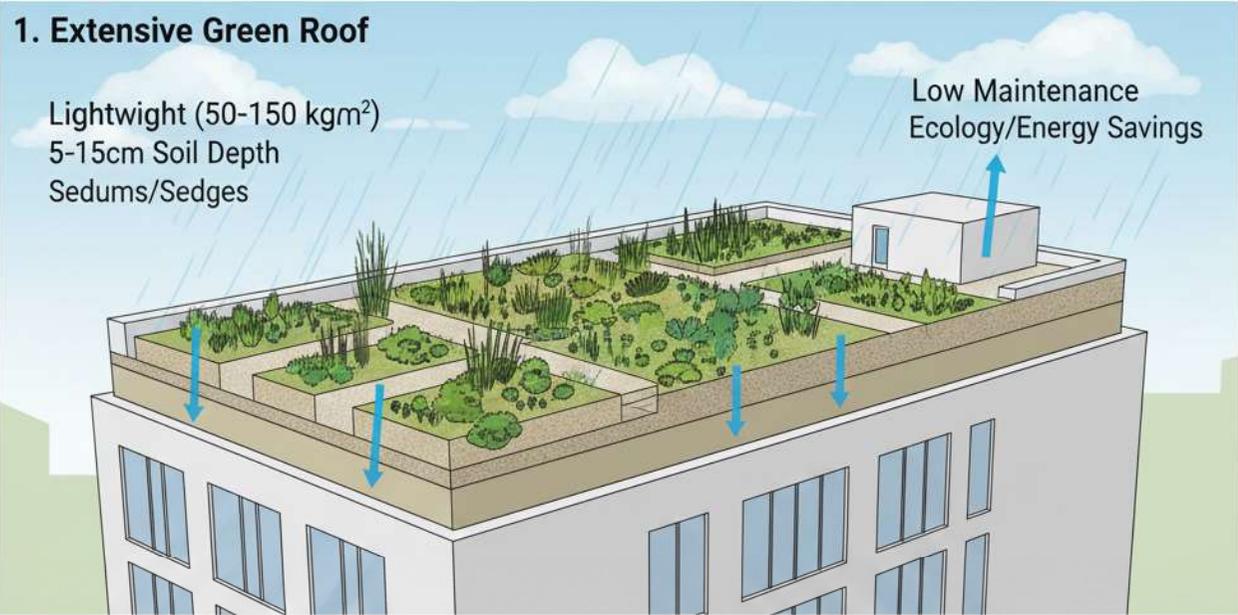
- Green roofs are layered systems covering roofs with vegetation, growing media, and drainage over waterproofing membranes to mimic natural landscapes while supporting building functions.
- They reduce urban heat islands by 2-5°C, retain 50-90% stormwater, and cut roof heat flux by 70-90% through insulation and evapotranspiration.

# Green roofs

## 1. Extensive Green Roof

Lightweight (50-150 kgm<sup>2</sup>)  
5-15cm Soil Depth  
Sedums/Sedges

Low Maintenance  
Ecology/Energy Savings

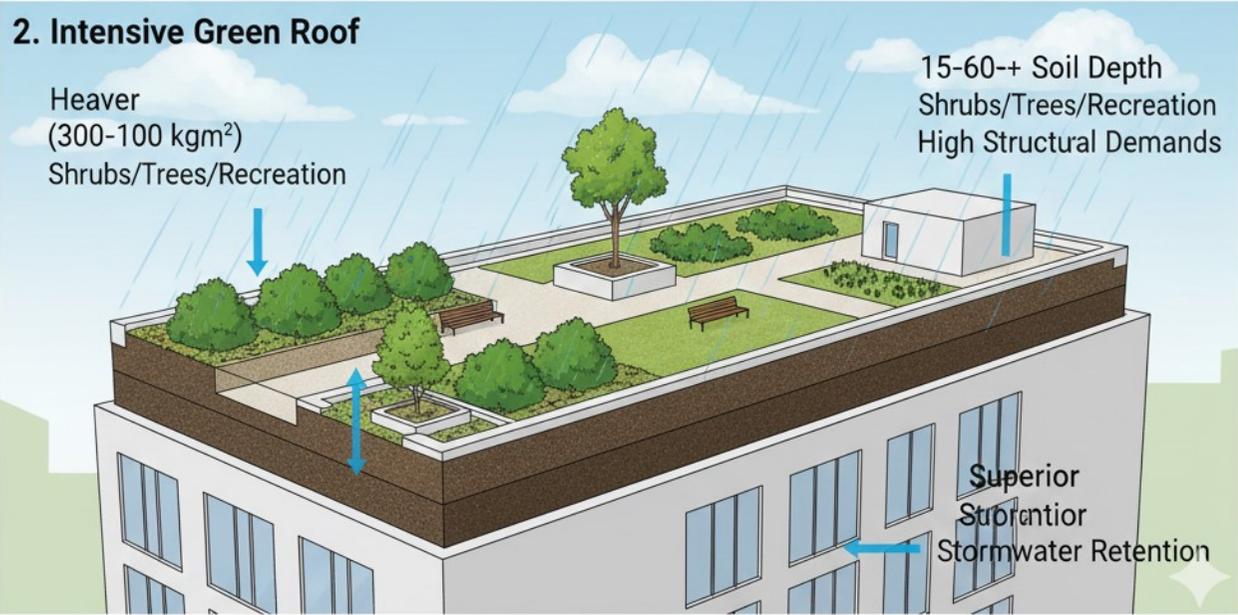


## 2. Intensive Green Roof

Heaver  
(300-100 kgm<sup>2</sup>)  
Shrubs/Trees/Recreation

15-60++ Soil Depth  
Shrubs/Trees/Recreation  
High Structural Demands

Superior  
Stormwater Retention



## Green roofs

- 1. Extensive green roofs:** Lightweight (50-150 kg/m<sup>2</sup> saturated), 5-15cm soil depth, droughttolerant sedums/sedges; low maintenance, minimal structural load (add ~100mm dead load); focus on ecology/energy savings.
- 2. Intensive green roofs:** Heavier (300-1000 kg/m<sup>2</sup>), 15-60cm+ soil, shrubs/trees for recreation; higher structural demands but amenity value like rooftop parks; superior storm water retention (up to 75% volume).