5.1.3 Energy Efficient Built Environment

An **energy efficient building** "*offers an appropriate environment for habitation with minimal energy consumption and wastage of energy, thereby maximizing energy conservation*" and *"balances all aspects of energy use in a building by providing an optimized mix of passive solar–design strategies, energy-efficient equipment, and renewable sources of energy"* (Sustainable Fuel Technologies Handbook, 2021).

Life Cycle Assessment for Building and its materials

Life Cycle Assessment (LCA) based on ISO14040 (2006) is being increasingly adopted in architectural design and construction, as it CA enables decision-making processes, such as, evaluating and selecting environmentally-friendly products and optimizing construction processes. In addition to assessing environmental impacts, LCA also facilitates estimating life cycle costs (LCC) and conducting life cycle energy analysis (LCEA). The incorporation of LCA into the building sector supports sustainable decision-making and promotes the evaluation of environmental, economic, and energy-related aspects throughout the life cycle of buildings. It is noteworthy that energy efficiency has been a primary focus in the environmental design of buildings, with the **use/operational phase** playing a dominant role in the LCA of buildings, due to the high energy demand associated with building operation. Operating energy, which includes energy for HVAC, domestic hot water, lighting, appliances, and building maintenance, is easily quantifiable and can account for up to 85% of total energy consumption and 70-90% of the environmental impact. However, many of these factors are beyond the control of designers, particularly during the conceptual stage, as they are spread over the decades-long lifespan of a building.

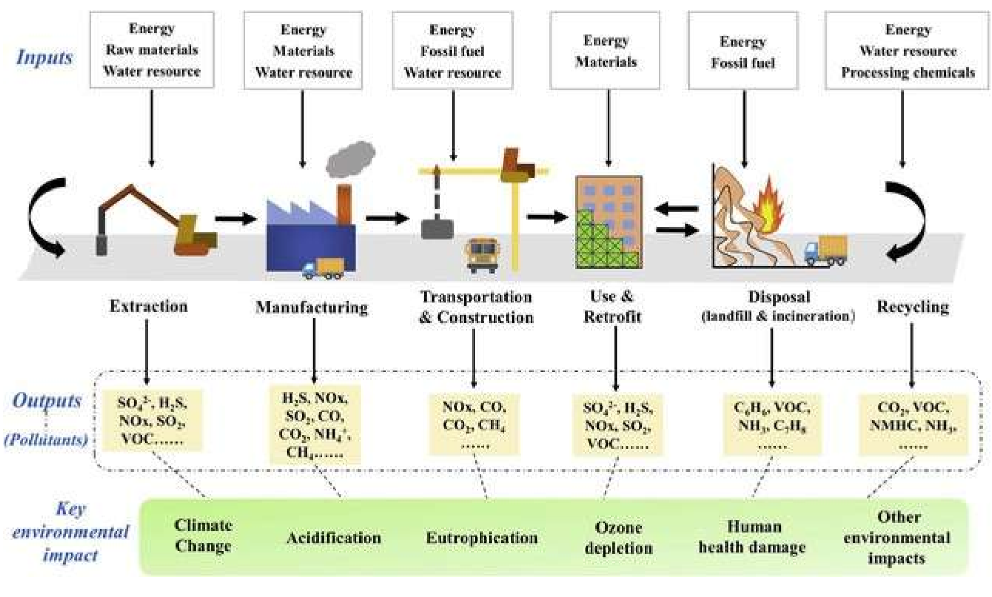

Fig. 5.4 : Key Environmental Impacts during Life Cycle of Building Materials (Huang, et al., 2020)

Therefore, the selection of appropriate materials, which is often emphasized as a directive for energy-efficient design, becomes a critical decision factor in the design process. It is recommended to consider material selection as early as possible, as it not only impacts the operational energy performance of the building but also influences the total embodied energy and potential environmental impact.

Embodied Energy and Embodied Carbon

From a life cycle perspective, the environmental impact and energy consumption of buildings are closely linked to the choice of materials. However, there is often a lack of alignment between the service life of materials (which determines the intervals for material renewal) and the service life of buildings (the duration of the operational phase). This can result in a *trade-off between material selection and building energy demand* and so, requires a holistic approach (Heeren et al., 2015) that considers the effects and trade-offs. For example, in a residential building, since the 'wood variant' is susceptible to solar and internal gains, and the 'concrete variant' isn't, the energy spent on demand for space cooling of wood is higher than concrete in spite of wood having lower environmental impact than concrete. However, for cool climates, a wooden structure and this very same property will be beneficial and energy-saving.

Every building material possesses an **'Embodied Energy' or Embodied Carbon**, which refers to the sum impact of all greenhouse gas emissions attributed to that material during its life cycle from extraction, till disposal. The after-use life cycle phase plays a significant role in determining the overall embodied energy of a building. LCA for the "end of life" (EOL) evaluates the environmental impact, including the energy required for demolition, at the end of a building's service life, as this is vital for decision-making since it has the potential to substantially reduce the environmental impact of the building through effective after-use strategies, such as, disassembly, remanufacturing, biodegrade-ability and the 3R principles of reduce, reuse, and recycle .

Lupíšek, et al. (2015) innumerate the **Design strategies** for reduction of embodied energy and embodied carbon (Subtask 4 of Annex 57) in three steps:

1. ***Reduction of amount of needed materials throughout entire life cycle***
    1.1. Optimization of layout plan
    1.2. Optimization of structural system
    1.3. Low-maintenance design
    1.4. Flexible and adaptable design
    1.5. Components' service life optimization

2. ***Substitution of traditional materials for alternatives with lower environmental impacts***
    2.1. Reuse of building parts and elements
    2.2. Utilization of recycled materials
    2.3. Substitution for bio-based and raw materials
    2.4. Use of innovative materials with lower environmental impacts

2.5. Design for deconstruction
2.6. Use of recyclable materials

3. Reduction of construction stage impact

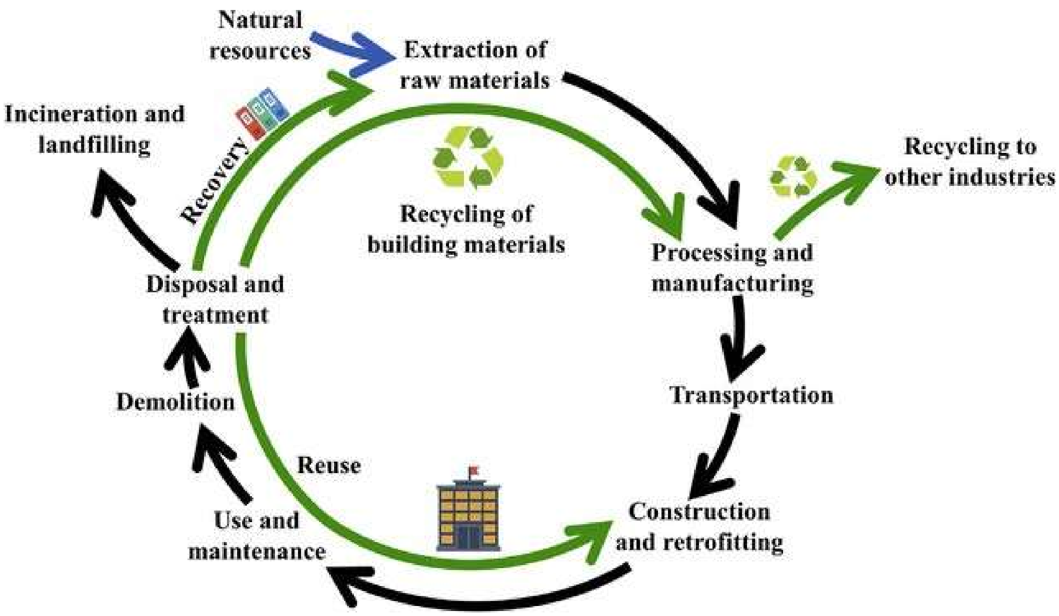

Fig. 5.5: Recycling of Building Materials (Huang, et al., 2020)

Building Materials and Recycling

A large number of building materials are **reusable and recyclable** (Kralj & MariČ, 2008) , such as, Wood and untreated timber, and Earthen Materials (*reusable/recyclable/biodegradable*); Metals, mainly Steel, Aluminium, Iron, Copper, Masonry and Bricks, and Glass and ceramic (*reusable/recyclable*); Asphalt and Concrete (*may be crushed and recycled*); and Gypsum/Drywall (*recyclable, sometimes biodegradable*). Some innovative, modern recycled building materials are ; **Plant-Based Polyurethane Foam Boards**, possessing good heat transfer resistance, quality sound insulation, and mould and insect resistance; **Hempcrete**, a sustainable, carbon negative alternative to concrete bound with hemp fibres; **Ecobrick**, a plastic bottle filled with small plastic waste; **Rammed Earth**, made of compacted, excavated earth from the construction site, mixed with concrete; **Chip[s]** board, is a fibre-reinforced bioplastic made from potato waste.

Recycling materials can contribute greatly towards **reducing impact** and can be achieved by;

- ***Identifying materials in existing buildings*** that can be salvaged and reused in new construction projects may include, structural elements, fixtures, flooring, doors, and windows.
- ***Establishing on-site recycling programs*** to process and reuse construction and demolition waste, and setting up in dedicated areas for sorting and separating different materials such as concrete, metal, wood, and plastics.
- ***Implementing comprehensive waste management plans*** for construction sites, with clear guidelines for sorting, separating, and recycling different types of waste generated during the construction process.
- ***Participating in material exchange networks*** or online platforms where builders, contractors, and suppliers can connect to exchange surplus materials.
- ***Collaborating with local recycling centers***, waste management facilities, and other stakeholders to establish efficient recycling systems for construction materials.

Incorporating design principles of '**Design for Disassembly'** make it easier to disassemble and separate materials during the end-of-life phase, by using modular construction techniques and joinery systems, for easy dismantling without damaging the materials, is a potential approach to carefully deconstruct buildings to preserve reusable materials.

5.1.4 LEED Rating

LEED, which stand for Leadership in Energy and Environmental Design, is a green building rating system developed by the US Green Building Council (USGBC). In India, Confederation of Indian Industry (CII) formed the Indian Green Building Council (IGBC) in year 2001 and has licensed the LEED Green Building Standard from the USGBC.

Policymakers, planners, and builders can adopt LEED and sustainable building practices as effective strategies to progress towards the UN SDGs. LEED categories contribute to the achievement of the SDGs in the following ways - conserving water, improving energy efficiency, reducing carbon emissions (GHGs), and minimizing harmful air pollutants to enhance environmental sustainability. LEED also supports education, job creation, improved health and well-being, strengthened community resilience, and more. It takes a holistic approach by considering all essential aspects that contribute to the overall quality of a building, rather than solely focusing on individual elements like energy, water, or health, and embraces a comprehensive perspective, recognizing the interplay and synergy among various factors to achieve optimal building performance.

The **primary objective** of LEED is to facilitate the design of good buildings that exude the following characteristics, as outlined by USGBC;

- *Reduce contribution to global climate change.*

- *Enhance individual human health.*
- *Protect and restore water resources.*
- *Protect and enhance biodiversity and ecosystem services.*
- *Promote sustainable and regenerative material cycles.*
- *Enhance community quality of life.*

Certification types and Credit scoring

There are **various kinds of LEED certifications** depending on the types and the phase of the building of projects, as follows;

- ***LEED Building Design and Construction*** (**BD+C**) For new construction or major renovations, and also includes applications for Schools, Retail, Hospitality, Data Centers, Warehouses & Distribution Centers, and Healthcare.
- ***LEED Interior Design and Construction*** (**ID+C**) for complete interior fit-out projects, Includes Commercial Interiors, and also includes applications for Retail and Hospitality.
- ***LEED Building Operations and Maintenance*** (**O+M**) for existing buildings that are undergoing improvement work or little to no construction. Includes Existing Buildings, and also includes applications for Schools, Retail, Hospitality, Data Centers, and Warehouses & Distribution Centers.
- ***LEED Neighbourhood Development*** (**ND**) for new land development projects or redevelopment projects containing residential uses, non-residential uses, or a mix. Projects can be at any stage of the development process, from conceptual planning to construction. Includes Plan and Built Project.
- ***LEED Homes*** for single family homes, low-rise multi-family (one to three stories) or mid-rise multi-family (four or more). Includes Homes, Multifamily Low-rise, Multifamily Midrise.
- ***LEED Cities*** for entire cities and sub-sections of a city. LEED for Cities projects can measure and manage their city's water consumption, energy use, waste, transportation and human experience.

To obtain **LEED certification**, a project accumulates points by adhering to prerequisites and fulfilling criteria related to carbon emissions, energy efficiency, water conservation, waste management, transportation, materials usage, and indoor environmental quality. The certification process involves a thorough examination and assessment by GBCI (Green Business Certification Inc.), which assigns points based on the project's adherence to LEED standards. The total number of points determines the level of LEED certification: *Certified* (40-49 points), *Silver* (50-59 points), *Gold* (60-79 points), or *Platinum* (80+ points). Notably, climate change accounts for 35% relate to climate change, 20% directly impact human health, 15% impact water resources, 10% affect biodiversity, 10% relate to the green economy, and 5% impact community and natural resources. In LEED v4.1, operational and embodied carbon have the most LEED credits associated to them.

LEED Credits and categories

The **major categories and their respective credits** are;

- ***Energy and Atmosphere (33 credits)***
  - Fundamental Commissioning and Verification [*prerequisite*]
  - Minimum Energy Performance [*prerequisite*]
  - Building-Level Energy Metering [*prerequisite*]
  - Fundamental Refrigerant Management [*prerequisite*]
  - Optimize Energy Performance [18]
  - Enhanced Commissioning [6]
  - Advanced Energy Metering [1]
  - Renewable Energy [5]
  - Enhanced Refrigerant Management [1]
  - Grid Harmonization [2]
- ***Location and Transportation (16 credits)***
  - Sensitive Land Protection [1]
  - High Priority Site and Equitable Development [2]
  - Surrounding Density and Diverse Uses [5]
  - Access to Quality Transit [5]
  - Bicycle Facilities [1]
  - Reduced Parking Footprint [1]
  - Electric Vehicles [1]
- ***Materials and Resources (13 credits)***
  - Storage and Collection of Recyclables [*prerequisite*]
  - Building Life-Cycle Impact Reduction [5]
  - Environmental Product Declarations [2]
  - Sourcing of Raw Materials [2]
  - Material Ingredients [2]
  - Construction and Demolition Waste Management [2]
- ***Sustainable Sites (10 credits)***
  - Construction activity pollution prevention [1]
  - Site Assessment [1]
  - Protect or Restore Habitat [2]
  - Open Spaces [1]
  - Rainwater Management [3]
  - Heat Island Reduction [2]
  - Light Pollution Reduction [1]
- ***Water efficiency (10 credits)***
  - Outdoor Water Use Reduction [*prerequisite*]

- Indoor Water Use Reduction [*prerequisite*]
- Building-Level Water Metering [*prerequisite*]
- Outdoor Water Use Reduction [2]
- Indoor Water Use Reduction [6]
- Optimize Process Water Use [2]
- Water Metering [1]

- ***Innovation (6 credits)***
  - Innovation in design [5]
  - LEED Accredited Professional [1]
- ***Regional Priority Credits (4 credits)***
- ***Integrative Process (1 credit)***

In the US Green Building (USGBC) annual list for **2021**, **India** achieved the remarkable position of **third in the world for LEED** Green buildings, with a total of 146 certified buildings and spaces, covering an impressive 2.8 million gross area square meters.

Other Green Building Certifications in India

Apart from LEED, the other 2 main green building certification systems in India, are; GRIHA (Green Rating for Integrated Habitat Assessment), India's own rating system jointly developed by TERI and the Ministry of New and Renewable Energy, Government of India, and BEE (Bureau of Energy Efficiency) developed its own rating system for the buildings and the Energy Performance Index (EPI).

GRIHA introduces a comprehensive approach of assessing 11 Parameters with 30 criteria accumulating to 100+5 maximum points (refer Fig. 6), across three stages:

1. ***Pre-construction stage:*** This stage addresses both on-site and off-site factors, such as the proximity to public transportation, soil type, land characteristics, location, existing flora and fauna, and natural landscape features before construction begins.
2. ***Building planning and construction stages***: This stage focuses on resource conservation, reducing resource demand, optimizing resource utilization efficiency, promoting resource recovery and reuse, and ensuring occupant health and well-being.
3. ***Building operation and maintenance stage***: This stage encompasses the operation and maintenance, monitoring and recording energy consumption, ensuring occupant health and well-being, and addressing factors that impact the local and global environment.

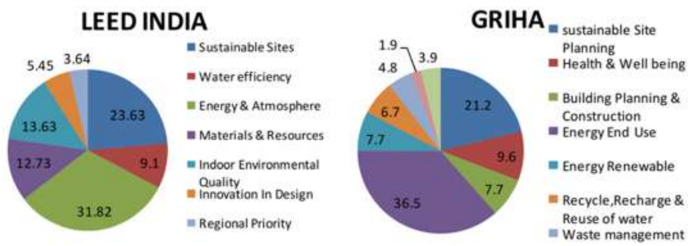

Fig. 5.6 : Performance criteria comparison of LEED and GRIHA Rating (Phadtare and Sande, 2015)

Ji et al., 2017, conducted a comparative analysis of GRIHA v2015 and LEED v4 for BD + C: New Construction and Major Renovation with respect to the three pillars of Sustainability and reported;

GRIHA v2015	**LEED v4 BD+C**
Strong focus on Environmental and Economic aspects, less Social	Has more balanced focus on all the three pillars
Has a dedicated section for assessment of socio-economic aspects of the laborers and service professionals, creating awareness on environment and design for accessibility, missing from LEED.	Has a section dedicated to *Regional Priority: Specific Credit,* and has social aspects like, open space access, bicycle facilities, diversity in use and quality views included in its assessment. Can be an addition to GRIHA.

GRIHA v.2019			
Section	**Criterion No.**	**Criterion Name**	**Maximum Points**
1. Sustainable Site Planning	1	Green Infrastructure	5
	2	Low Impact Design	5
	3	Design to Mitigate UHIE	2
2. Construction Management	4	Air and Soil Pollution Control	1
	5	Top Soil Preservation	1
	6	Construction Management Practices	2
3. Energy Efficiency	7	Energy Optimization	12
	8	Renewable Energy Utilization	5
	9	Low ODP and GWP Materials	1
4. Occupant Comfort	10	Visual Comfort	4
	11	Thermal and Acoustic Comfort	2
	12	Maintaining Good IAQ	6
5. Water Management	13	Water Demand Reduction	3
	14	Wastewater Treatment	3
	15	Rainwater Management	5
	16	Water Quality and Self-Sufficiency	5
6. Solid Waste Management	17	Waste Management-Post Occupancy	4
	18	Organic Waste Treatment On-Site	2
7. Sustainable Building Materials	19	Utilization of Alternative Materials in Building	5
	20	Reduction in GWP through Life Cycle Assessment	5
	21	Alternative Materials for External Site Development	2
8. Life Cycle Costing	22	Life Cycle Cost Analysis	5
9. Socio-Economic Strategies	23	Safety and Sanitation for Construction Workers	1
	24	Universal Accessibility	2
	25	Dedicated Facilities for Service Staff	2
	26	Positive Social Impact	3
10. Performance Metering and Monitoring	27	Commissioning for Final Rating	7
	28	Smart Metering and Monitoring	0
	29	Operation and Maintenance Protocol	0
Total Points			100
11. Innovation	30	Innovation	5
Grand Total Points			100 + 5

Fig. 5.7 : GRIHA v2019 Criteria and Points (source : www.grihaindigo.org)