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A Review paper on Sustainability in Built Environment

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Abstract : . A sustainable built environment is multiple-dimensioned (environment, society, and economy), life cycle viewed, and extends over a vast range of subjects from material manufacturing to building design and engineering to indoor environmental quality to community cohesion and urban planning. Spatially, built environment refers to individual buildings extending in scale from a single-standing site to an area with multiple buildings and open space, accompanied by intensive socio-economic interaction between users, affiliated facilities, and urban support services.

For example, energy efficiency is the key factor at the building level, as buildings account for a significant share of total energy consumption and offers a large potential for energy savings. Specifically, at this level, the integration of renewable energy systems, such as photovoltaic and solar thermal systems, will play a vital role in achieving a green and efficient built environment.

Furthermore, a sustainable built environment is associated with concepts and ideas such as the integration of renewable energy systems, BIPV, zero-energy buildings, vertical farming, adaptive building skins, affordable housing, integrative open public spaces and landscapes, age-friendly built environments, etc. The mechanisms and actions entail a careful, simultaneous consideration of various aspects and complex processes related to the built environment and its users, including inevitable balancing between environmental, economic, social, and cultural sustainability, while enabling appropriate connectedness and harmonization between micro, and macro urban levels.

This paper will explain the following Sustainable Development Goals in Urban planning and processes for a sustainable development

Keywords- Indoor environmental air quality, Energy efficiency, BIPV- building integrated photovoltaics, Zero- energy buildings, Urban planning.

I. Introduction

The Sustainable development strategies' focuses on five dimensions: economic sustainability, social sustainability, ecological sustainability, sustainable spatial development, and cultural continuity. Thus, sustainable housing is one of the fundamental pillars of sustainable development, and sustainable urban development can be discussed in this context. The target of the sustainable urban development process is to achieve the status of "sustainability" in urban communities and also to create or strengthen the sustainability characteristics of an economic, social, cultural, and environmental city. (Shahreen Fareea, 2009)

Urban planning and design for sustainable development is the process of shaping the physical setting for life to deal with the three-dimensional spaces in cities, towns, and villages that concerns environmental, social, and economical factors. In a contemporary context, many cities and urban residents will be directly affected by many of the impacts of environmental changes, which include increased intensity and frequency of extreme weather events, heat waves, flooding from sea-level rise, water shortages, and other effects. On the other side, in the big cities, migration is increasing greatly for the need of work, study purposes, and treatment facilities and the result is an economical crisis, urban sprawl, high density, transport problem, increase energy use, and pollution. (Shahreen Fareea, 2009)

The question this paper will be answering is "How do we bring about sustainability in the built environment?"

1.1 Defining sustainability

A wide range of definitions exists for sustainability and sustainable development. One of the most widely used definitions refers to ensuring that the needs of current populations are met without negatively affecting future populations: 'development that meets the needs of current generations without compromising the ability of future generations to meet their needs and aspirations (World Commission on the Environment and Development, 1987, p. 43). Translating this definition into action is difficult. 'Needs' and 'aspirations' are subjective and interpretations vary on what this means. Explicit reference is also not made to environmental limitations which determine whether current and future generations can meet their needs (Button, 2002).

Designing for sustainable development requires awareness of the full short and long-term consequences of any transformation of the environment, society, and economy. Finally, we find that urban planning and design for sustainability is the process of shaping the physical setting for life to deal with the three-dimensional spaces in cities, towns, and villages that concerns environmental, social, and economical factors. In cities, it is also important for landscape. Landscape planning prescribes alternative spatial configurations of land uses, which is widely understood as a key factor in planning for sustainability (Ahern, 2005).

2. Development Goals and strategies for a better sustainable built environment

2.1 Urban planning and processes for sustainable development:

2.1.1 Sustainable urban-rural planning;

One of the most discernible trends when observing the current dynamics of cities and urban regions is urban sprawl. Urban sprawl can be defined as the low-density expansion or 'leapfrog development of large urban areas into the surrounding rural landscape. Other definitions also include the fact that such development is often accompanied by weak regional land use planning and control (e.g. EEA & JRC 2006, Reckien & Karecha 2007). It is essential for future development; a clear relationship is established between urban design and local climate at the macro/regional level as well as at the local micro-climatic level. Based on understanding climate change to improve the design processes, the planner uses proper materials, skills, technologies, and tools. In urban design the issues concerns are:

- Site layout, exposure, and orientation.
- Form size and layout of a new structure and open spaces.
- Relationship and effect on surrounding building, open space, topography, and landscape.
- Use of passive and active design features matched to the climate.
- Choice of the use of material, construction, and service system.

A sustainable urban environment can be brought about by promoting urban agriculture and preserving agricultural land in urban areas, supply chains can be shortened and the amount of CO_2 emitted when transporting food from rural to urban areas is reduced to a great extent. Producing and selling more fresh food within the city itself can reduce the environmental impact of food distribution, and can increase opportunities for inclusive local supply chains, and improve access to nutritious foods, for example through farmers' markets. New sustainable solutions for urban planning problems can include green buildings and housing, mixed-use developments, walkability, greenways, and open spaces, alternative energy sources such as solar and wind, and transportation options. Good sustainable land use planning helps improve the welfare of people and their communities, shaping their urban areas and neighborhoods into healthier, more efficient spaces.

2.1.2 Urban Governance

Good urban governance can be achieved by building on the social dimension of governing. It can be assumed that public participation and urban movements are factors that will foster the acceptance of a new approach towards urban planning based on the values of inclusiveness, openness, democratic debate, and the common good. Participation is still insufficient both in terms of public awareness, education, and engagement and in terms of tools to support it, despite it being one of the key principles of 'good urban governance. Residents do not always participate in the development of public space due to insufficient access to information and lack of transparency in the process of urban transformation. The process of civic participation is most often implemented in the form of public consultations held in case of establishing new local development plans. Public consultations should not only serve the purpose of coordinating local regulations between the residents and other stakeholders and administrative institutions but their most important function should be educational. The process of decision-making, which is more important than the decisions themselves, is primarily a tool for improving social and spatial awareness and developing active citizenship (A. Baranowski, 2017)

2.1.3 Smart cities

Cities that provide the greatest of opportunities, are accelerators for social changes, promote innovation, have connected infrastructure, and easily adopt technology, with the capacity to scale up. However, these cities are burdened with issues like handling urban wastes, conserving fossil fuels, facilitating affordable and timely healthcare systems, providing efficient traffic management, and transparency in governance. These concerns gave birth to innovative, technology-based, and sustainable urban spaces called Sustainable Smart Cities (SSC). SSC deploys the technologies to monitor its community and provide sustainable and affordable solutions to urban spaces. This demands a stable, secure, interoperable, and reliable telecommunication network, to support applications and services in urban areas. The recent developments in the area of the Internet of Things (IoT) assure to drive and support this development of SSCs. (V. Padmapriya & D.N. Sujatha, in Blockchain for Smart Cities, 2021)

2.1.3.1 Smart infrastructure

Smart City focuses on basic infrastructure, uses “smart” solutions to upgrade infrastructure and amenities, and depends on area-based growth. The true “smartness" of a "Smart City" is to use IoT in a structured, safe, secure, accountable, and harmonized way to meet the dreams and expectations of its people, concerning:

Dimensions	Description	Strategy
	ICT-enabled lifestyles, behavior, and consumption.	
Smart Living	Healthy and safe living in a culturally vibrant city.	*vision*
	Good quality housing.	
	E-business and e-commerce and increased productivity.	
	Advanced manufacturing and delivery of services.	
Smart Economy	Local and global interconnectedness.	

	ICT-enabled innovation: *products, services,* and *business.*	
Smart People	E-skills: access to education and training.	
	Human resources and capacity management.	*mission*
	Improving creativity and innovation: *products* and *services.*	
	Data analytic tools- *making decisions.*	
Smart mobility	ICT-supported transport and logistics systems.	
	Prioritizes clean and often nonmotorized options	
	Costs and CO_2 savings.	
	Data for long-term planning.	
Smart Governance	Smart objectives: transparency; ICT open data; e-government in participatory decision making; and new services.	*mission*
	ICT infrastructure, hardware, and software.	
	Smart processes fueled by data.	
Smart environment	Smart energy including renewables	*opportunistic*
	ICT-enabled energy grids, metering, and pollution controls.	
	Buildings and amenities: green buildings and urban planning.	
	Resource use efficiency.	

Table 1-(Source - V. Padmapriya & D.N. Sujatha, in Blockchain for Smart Cities, 2021)

2.1.4 Urban Farming

Urban farming can be practiced in various ways, but it refers to crop and livestock production within cities and surroundings. Urban farming (also known as urban agriculture) takes advantage of every inch of private or public space and can involve anything from rooftop farming to balcony gardening, from farming in parking lots to farming along roadsides. Urban farming plays a large part in contributing to sustainable urban development. As more and more people are living in cities, urban agriculture is emerging as an attractive means of catering to citizens with food. At the same time, urban farming is an important strategy for the reduction of hunger and poverty, improvement in resident health, and climate change mitigation and adaptation. The diagram below (Fig 1.) indicates the many links food and the food system has with most aspects of urban life. It gives weight to spatial aspects related to urban food and urban agriculture. These findings suggest that urban agriculture can contribute to a liveable and sustainable city in many ways. Liveability is important as urban agriculture can create interactive spaces, reduce anti-social behavior, and provide urban amenities and green space.

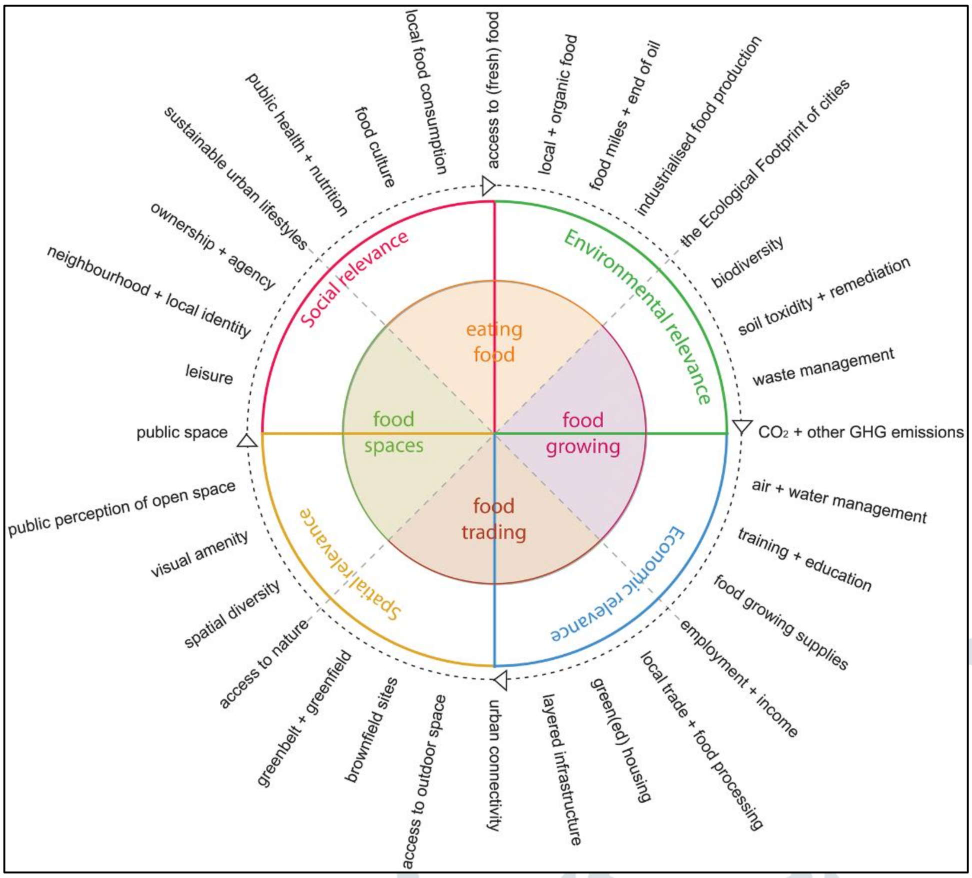


Figure 1-Links Between the Food System and Urban Life

Source: Blue-Green Systems

2.1.5 Participatory architecture and people-centered planning and design practices

PA stands for the democratization of architectural design processes (Sanoff, 2010). It arises from the need to generate alternative ways of doing architecture that can afford community members "to reconnect with their sense of agency through engagement in space and place" (Dodd, 2020, p.1), and from the need to produce positive changes of future-making with people (Luck, 2018). PA moves away from considering spaces as static, neutral, or finite, rather, spaces are understood as transitional, changeable, evolving, and dynamic. It displaces the hierarchical norms commonly associated with professional architectural practice and makes explicit that the creation of space should be a shared enterprise (Awan et al., 2011, p. 29), transforming relationships between professionals and laymen by sharing agency. In this regard, the role of the architect shifts away from the perspective of an expert, who works alone (within a design capsule), to that of a facilitator, who creates collective opportunities for community members to identify and understand their needs (Murphy & Hands, 2012), and enable them to change their spatial situations. Figure 2 below illustrates the principles of engagement for participatory design.

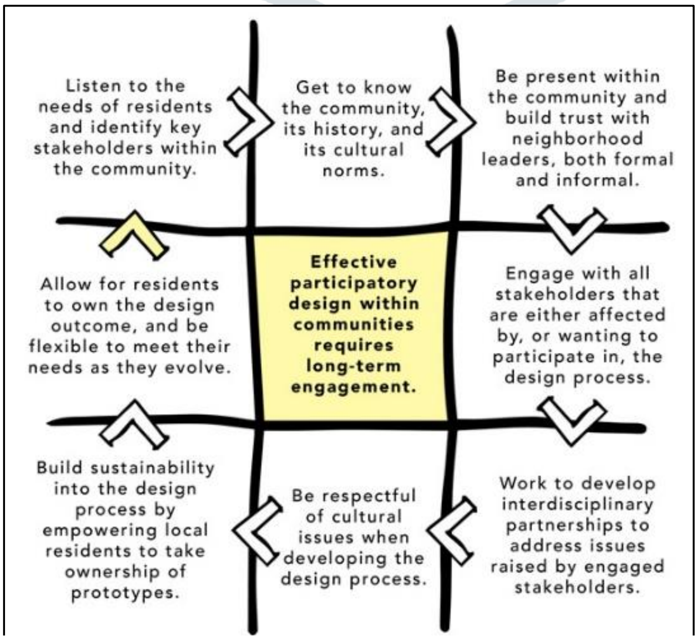


Figure 2 Principles of engagement for participatory design
Source- Matt Kleinmann April 2016

2.2 Affordable and Clean Energy

2.2.1 Zero energy and carbon buildings

A net zero-energy building (ZEB) is a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies. At the heart of the ZEB, the concept is the idea that buildings can meet all their energy requirements from low-cost, locally available, nonpolluting, renewable sources. At the strictest level, a ZEB generates enough renewable energy on-site to equal or exceed its annual energy use. The following concepts and assumptions have been established to help guide definitions for ZEBs. A good ZEB definition should first encourage energy efficiency, and then use renewable energy sources available on-site. Passive solar heating and daylighting are demand-side technologies and are considered efficiency measures. Energy efficiency is usually available for the life of the building; however, efficiency measures must have good persistence and should be "checked" to make sure they continue to save energy. It is almost always easier to save energy than to produce energy. (Torcellini et al , 2004). Table 2 below discusses the ZEB renewable energy supply option hierarchy

No.	ZEB supply - side Options	Examples
1	Reduce site energy use through low-energy building technologies	Daylighting, High - efficiency HVAC equipment, natural ventilation, evaporative cooling, etc.
On- Site Supply Options		
1	Use renewable energy sources available within the building's footprint	PV, Solar hot water, and wind mills located on the building
2	Use renewable energy sources available at the site	PV, Solar hot water, low impact hydro, and wind located on- site, but not on the building.
Off- Site Supply Options		
1	Use renewable energy sources available off- site to generate energy on site	Biomass, wood pellets,ethanol, or biodiesel that can be imported from off- site or waste streams from on- site processes that can be used on-site to generate electricty and heat.
2	Purchase off- site renewable energy sources	Utility-based wind, PV, emissions credits or other "green" purchasing options. Hydroelectric is sometimes considered.

Table 1 ZEB Renewable Energy Supply Option Hierarchy, (Source- Torcellini et al, 2004)

2.2.2 Integration of renewable energy technologies into the built environment

Renewable energy resources universally used for building applications include solar, wind, geothermal heat pumps, and biomass. Before selecting an appropriate renewable energy technology to apply to an existing building retrofit project, it is important to first consider several factors. Examples of these factors include:

• Available renewable energy resources at or near the building site
• Available area for siting of the renewable energy technology
• Cost of energy purchased from the electrical or thermal energy provider for the building
• Available incentives for offsetting the installation cost of the renewable energy system
• Local regulations affecting renewable energy systems
• Desire to preserve or not alter existing architectural features

Figure 2, CII –Soharab JI Godrej green business center, Hyderabad, Source- Greenroofs.com

2.2.3 Implementation of solar systems (photovoltaics (PV), solar thermal systems) into the built environment

Photovoltaic system

Photovoltaic (PV) systems directly convert solar energy into electrical energy. PV energy systems are designed to generate some or all of the electrical energy demand of a building by installing PV modules onto the rooftop. The building remains connected to the main power grid as any energy needed beyond what the PV system can provide can still be taken from the main grid.

PV systems for buildings are classified into two types; the grid-tied systems which have no battery backup capability and stand-alone systems which are grid-connected and backup batteries are included. The operation of grid-tied (grid-connected) systems directly depends on the availability of utility. This type of PV system is very reliable with high efficiency and easy to integrate into the building, and in extension, these are cost-effective systems in comparison to the stand-alone system. (Alenezi, 2022)

Solar Thermal Systems

Solar water heating can be a cost-effective way to generate hot water or air and eliminate both the cost of electricity or fossil fuel as well as the associated environmental impacts. Solar Hot Water Systems. Solar hot water systems use a collector to absorb and transfer heat from the sun to water, which is stored in a tank until needed. These systems are categorized by the temperature at which heat is most efficiently delivered and the collector type that is best suited for that delivered temperature, including low-temperature (unglazed collectors), mid-temperature (flat-plate collectors), and high-temperature (evacuated tube collectors). In general, solar water systems are reliable and low maintenance because they have few moving parts. The primary components of a solar water heating system are the collectors and heat transfer systems, which include a heat exchanger, pumps, hot water storage, and controls. (Alenezi, 2022)

2.2.4 Geothermal technology

Geothermal technology harnesses the Earth's heat. Just a few feet below the surface, the Earth maintains a near-constant temperature, in contrast to the summer and winter extremes of the ambient air above ground. Further below the surface, the temperature increases at an average rate of approximately 1°F for every 70 feet in depth. In some regions, tectonic and volcanic activity can bring higher temperatures and pockets of superheated water and steam much closer to the surface.

Three main types of technologies take advantage of Earth as a heat source:

- Ground source heat pumps
- Direct use geothermal
- Deep and enhanced geothermal systems

Geothermal energy is considered a renewable resource. Ground source heat pumps and direct-use geothermal technologies serve heating and cooling applications, while deep and enhanced geothermal technologies generally take advantage of a much deeper, higher-temperature geothermal resource to generate electricity. (Environmental protection agency)

How It Works

The steps below describe how a heat pump works in "heating mode"—taking heat from the ground and delivering it to a building—and "cooling mode," which removes heat from the building and transfers it to the ground.

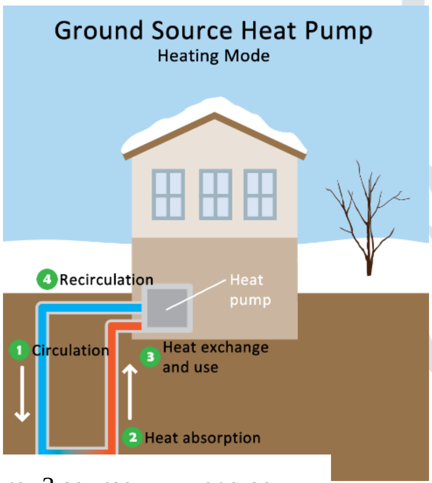
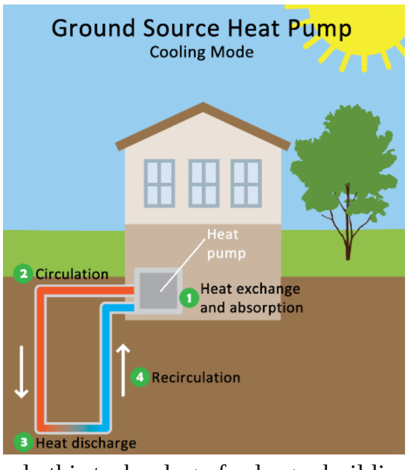


Figure -3 source-www.epa.gov



Heating Mode

1. **Circulation:** The above-ground heat pump moves water or another fluid through a series of buried pipes or ground loops.
2. **Heat absorption:** As the fluid passes through the ground loop, it absorbs heat from the warmer soil, rock, or groundwater around it.
3. **Heat exchange and use:** The heated fluid returns to the building where it is used for useful purposes, such as space or water heating. The system uses a heat exchanger to transfer heat into the building's existing air handling, distribution, and ventilation system, or with the addition of a desuperheater, it can also heat domestic water.
4. **Recirculation:** Once the fluid transfers its heat to the building, it returns at a lower temperature to the ground loop to be heated again. This process is repeated, moving heat from one point to another for the user's benefit and comfort.

Cooling Mode

1. **Heat exchange and absorption:** Water or another fluid absorbs heat from the air inside the building through a heat exchanger, which is the way a typical air conditioner works.
2. **Circulation:** The above-ground heat pump moves the heated fluid through a series of buried pipes or ground loops.
3. **Heat discharge:** As the heated fluid passes through the ground loop, it gives off heat to the relatively colder soil, rock, or groundwater around it.
4. **Recirculation:** Once the fluid transfers its heat to the ground, the fluid returns at a lower temperature to the building, where it absorbs heat again. This process is repeated, moving heat from one point to another for the user's benefit and comfort.

The above-ground heat pump is relatively inexpensive, with the underground installation of ground loops (piping) accounting for most of the system's cost. Heat pumps can support space heating and cooling needs in almost any part of the country, and they can also be used for domestic hot water applications. Increasing the capacity of the piping loops can scale this technology for larger buildings or locations where space heating and cooling, as well as water heating, may be needed for most of the year. (EPA)

2.2.5 BIPV

Figure- 5 Applications of BIPV, (Source- Metsolar)

A Building Integrated Photovoltaics (BIPV) system consists of integrating photovoltaic modules into the building envelope, such as the roof or the facade. By simultaneously serving as building envelope material and power generator, BIPV systems can provide savings in materials and electricity costs, reduce the use of fossil fuels and emission of ozone-depleting gases, and add architectural interest to the building.
While the majority of BIPV systems are interfaced with the available utility grid, BIPV may also be used in stand-alone, off-grid systems. One of the benefits of grid-tied BIPV systems is that, with a cooperative utility policy, the storage system is essentially free. It is also 100% efficient and unlimited in capacity. The on-site production of solar electricity is typically greatest at or near the time of a building's and the utility's peak loads. The solar contribution reduces energy costs for the building owner while the exported solar electricity helps support the utility grid during the time of its greatest demand. (S. Strong, 2016). The application of these BIPV panels can be on the facades, rooftops, and glazing.

2.2.6 Green building envelopes

The building envelope is the main component in a building responsible for the building's ability to protect the indoor environment from external environmental impacts. It is the interface between the external environment and the indoor environment. It protects the indoor environment against adverse environmental effects and subsequently regulates energy consumption, resource consumption, and environmental degradation (Irene and Robert, 2007). Apart from its protective and regulatory functions, the building envelope controls the solar and thermal flow, as well as moisture flow in and out of the building. It also controls the indoor air quality, fire, wind, rain, and acoustic effects on the building. This suggests the need to make building envelopes sustainable as an alternative approach for achieving building sustainability through sustainable envelope design. Figure 7, illustrates the regulatory and protective functions of building envelope in a building. These regulatory activities of the building envelope help to achieve building sustainability. Building envelope protects the building against environmental impacts such as wind, rain, temperature difference, vapor pressure difference, industrial pollution, solar radiation, and soil temperature (Green Building, 2011). Environmental impact is an important sustainability factor that influences other sustainability factors such as energy efficiency, material efficiency, and external benefit of building in terms of comfort conditions.

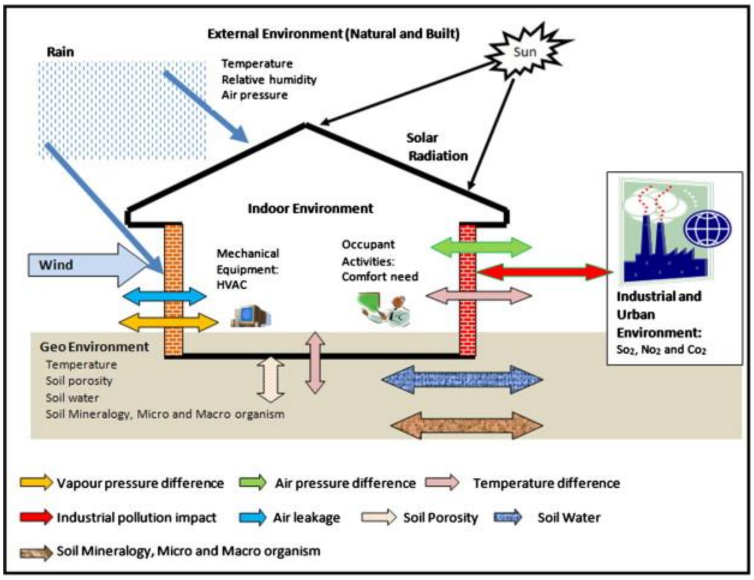


Figure 6 Environmental loads on the building envelope, (source- Joseph Iwaro, 2013)

2.3 CIRCULAR ECONOMY

In the Circular Economy model, the end-of-life building materials should be reused and their components and parts deconstructed, to act as material banks for new buildings, keeping the components and materials in a closed loop (Hopkinson et al., 2019) Circular economy is an economic model that favors the preservation of natural resources and decoupling of economic growth from material consumption over the entire lifecycle of products and services. It contradicts the linear (take, make, dispose of) economic system that is still widely adopted across industries. The key to a circular economy is closing the loop of products and raw materials, keeping them in use as intensively and as long as possible, and preventing wastage and waste as much as possible (along the Ladder of Circularity (10-R)). When discarded, products and materials are reused and recycled. Where new materials are added, they have a low environmental footprint, e.g. natural, renewable and regenerative materials used instead of fossil-based primary materials. Figure 8, illustrates the elements of a circular economy.

A circular economy approach not only enables a higher residual value but above all far better total costs of ownership. At the end of an asset's lifespan, high-quality recycling and reuse of materials can address the huge amounts of construction and demolition waste, resource scarcity, and environmental impact associated with material production.

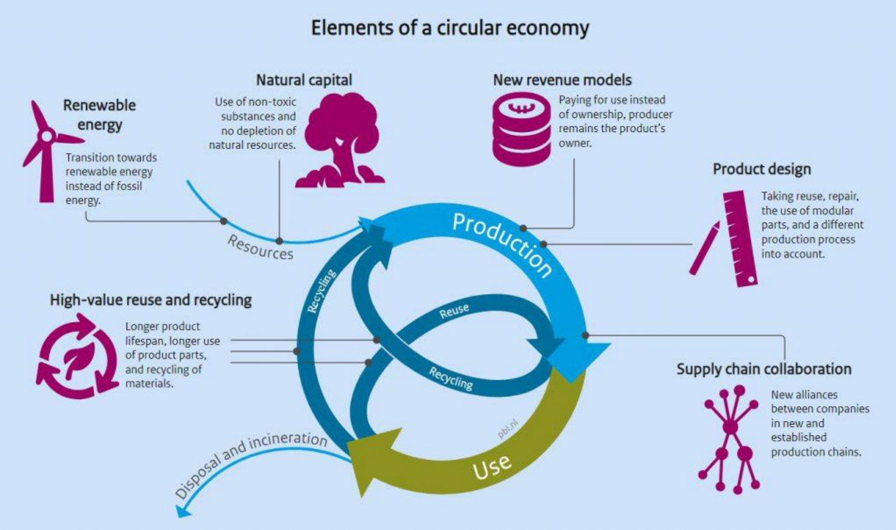


Figure 7- Elements of a circular economy (SOURCE- Morris Misel,2021)

2.4 Adaptability of buildings

Adaptability refers to the capacity of buildings to accommodate substantial change. Throughout a building's lifetime, change is inevitable, both in the social, economic, and physical surroundings and in the needs and expectations of occupants. All other things being equal, a more adaptable building will be utilized more efficiently, and stay in service longer, because it can respond to changes at a lower cost. A longer and more efficient service life for the building may, in turn, translate into improved environmental performance over the lifecycle.

The concept of adaptability can be broken down into several simple strategies that are familiar to most designers:

- Flexibility, or enabling minor shifts in space planning;
- Convertibility, or allowing for changes in use within the building; and
- Expandability, (alternatively shrinkability) or facilitating additions to the quantity of space in a building. In practice, these strategies can be achieved through changes in design, and the use of alternative materials and technologies.

Adaptability is closely related to but different from two other design strategies that attempt to enhance long-term environmental performance:

- **Durability:** selecting materials, assemblies, and systems that require less maintenance, repair, and replacement. Since durability extends the useful lifetime of materials and technology in a building, it is complimentary to adaptability.
- **Design for Disassembly:** making it easier to take products and assemblies apart so that their constituent elements can more easily be reused or recycled. Designing for disassembly can reduce the costs and environmental impact associated with adapting buildings to new uses. It is also possible to reduce overall environmental costs by purposely designing a building for a shorter life, and easier disassembly and reuse of components and materials – as is the case with many temporary exhibition halls. (P. Russell, S.Moffatt. 2001)

3. Discussions

To incorporate sustainable development concepts in a built environment, all stakeholders must be involved in the design. The successful design of sustainable buildings must consider all competing sustainable development factors to achieve the goal of building sustainability. The problem of building sustainability in the construction industry can be solved if the concept and principle of sustainable development were taken into consideration at the early stage of building design (Baragatti, 2004; De Dico, 2005; Mohammed and Iqbal, 2005).

Hence, the future of building development and its surrounding environment depends on the level of sustainable development initiatives and principles of sustainable practice incorporated into

the building envelope. Furthermore, sustainable design is a design approach put in place to promote the environmental quality and the quality of the building's indoor environment by reducing negative impacts on the building and the natural environment (McLennan, 2004).

The four inter-related areas for sustainable development are:

- The futurity principle emphasizes inter-generational equity and the need to minimize environmental resources for future generations through resource recycling and reviewable process.

- Public participation is an important strand that defines sustainable development and its role in influencing sustainable design decisions. It involves the participation of building and construction experts in sustainable devolvement decision-making.
- Environment emphasized the preservation of the ecosystem, energy conservation, and resource conservation for future building and envelope development.
- Equity promotes equality between the present generation and future generations by ensuring equal access to natural and environmental resources.
- Therefore, it is imperative that sustainable development concept that involves sustainable initiatives such as life cycle analysis, and energy conservation strategies be incorporated, to achieve building sustainability. Sustainable design will help in promoting green buildings and sustainable practices in the building industry. (Joseph Iwaro, Abrahams Mwasha, 2014)

4. Conclusion

Nowadays, we are facing a lot of environmental impacts due to urbanization. There is an increase in demand for shelters which in turn increases the consumption of energy, resources, and raw materials which are responsible for increasing the carbon footprint and henceforth impacting the environment and human health in a harmful way. Buildings account for the maximum resource consumption and therefore designing for a sustainable built environment is the only solution. In designing a built environment for sustainability the health and lifestyle of inhabitants are enhanced and there is the efficient use of resources throughout the lifecycle of the building (material production, construction planning, design, construction, operation, and maintenance) with minimal impact on the surrounding environment. The sustainable building expands on and complements the classical building design considerations of economy, utility, durability, and comfort.

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