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Hybrid Energy Harvesting System based Sustainable Building

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Abstract - *The proposed sustainable building is based on hybrid energy harvesting using solar energy, peizo-electricity and radio frequency (RF) as the energy source to satisfy the energy needs of wireless sensors used in building for smart home automation system by eliminating the traditional method of using batteries and external power lines. In addition to this a building can be made sustainable by incorporating solid waste management system, rain water harvesting system, gray water management system and by using sustainable building materials. An innovative daylight system can also be used to light up the building naturally using solar tubes and top lighting system which also adds up in making the building sustainable. Thus multiple resources are conserved and reused for making smart home automation system and sustainable building possible in near future.*

Key Words: sustainable building, hybrid energy harvesting, wireless sensors, smart home automation system, solar tubes.

1. INTRODUCTION

A building is made green and intelligent by incorporating three core technologies: building automation system, wireless technology and battery less device. The battery less devices brings in energy efficiency, flexibility, comfort and security by saving time and cost which outcomes the traditional system. The traditional system includes conventional wiring which is not flexible and cost effective and that of batteries causes pollution which needs high maintenance. And these systems have restrictions in positioning and orienting sensors according to customer needs. Thus the sensors are made self-powered to avoid these problems by using energy harvesting systems which helps in avoiding hindrance from noise and dirt.

The sustainable buildings include hospitals, hotels, small commercials, prefabs, single houses, flats and schools where worldwide 250000 buildings are made sustainable. The concept of sustainability includes working on energy/electricity, water, solid waste and materials. When energy is considered three main concepts come in to picture are day lighting, wireless sensors and battery less energy harvesting system. When day lighting is considered, their effective usage in buildings like using solar tubes in top of the building to direct the sunlight in to building (to avoid usage of lights running in electricity) and also working in placement of windows for directing sunlight into the building.

Numerous wireless sensors are used in the smart home automation system to sense any changes in ambient temperature or lightings etc which are powered through batteries which needs maintenance and regular replacements. Thus if a sensor is made self-powered by using energy harvesters will eventually reduces cost and time. In addition instead of using one energy source to harvest, multiple sources can be combined and harvested to improve the energy efficiency [1]. From literature multiple sources like piezo-electricity [2], solar energy, vibration energy [3], super capacitors, Li batteries [4] and nano-generator [5] are used for energy harvesting. The location and orientation is much concerned when piezo-electricity is used as energy for harvesters which can be placed in floors in building where high traffic area is considered. When solar energy is considered silica is used in harvesting which is costly so instead of using silica, silica based polymer is used as coating in windows and panels of building. The applications of self-powered systems include wireless bio sensing, infrastructure monitoring, sensing network, personal electronics and national security system. It also has applications in wireless sensor networks used for temperature monitoring, smart home automation and smart cities.

Then the water must be managed properly in building, one is rain water harvesting and next is grey water management. The gray water management is done by employing SOAP technique where water from sink, laundry and bath tubs are disinfected in the morning and re-circulated through the building during night for delivering heat energy to the floors of the building and then the water is again reused for laundry and flushing [6]. The solid waste management system is also employed for electricity generation. Novel materials are used in buildings to make building sustainable too.

2. DESIGN OF SUSTAINABLE BUILDINGS

2.1 Needs of Sustainable Buildings

In olden days, the local or vernacular architecture done by the people themselves had a lot of sustainable

practices mainly based on context and climate such as courtyards, verandah, mud walls, thatched roof, red oxide flooring and Aathangudi tiles. But due to introduction of various new technologies and modern materials, contemporary architecture style arrived, which reduced thinking and planning building in a sustainable way [7].

2.2 Principles of Sustainable Buildings

a. Optimize site potential
b. Reduce consumption of non-renewable resources
c. Minimizing waste
d. Recycling and re-usage of resources
e. Reduce negative impacts on the environment and comfort of building occupants
f. Reduce carbon emission from building sector
g. Protect and consume water
h. Enhance indoor environment quality

2.3 Practices of Sustainable Buildings

When we reduce the energy demand by planning windows, green roofs, planning proper landscape and building orientation properly (passive design), then the reduced energy used can be met by various energy harvesting (active design) principles as shown in **Fig -1** and **Fig -2**. **Fig -3** depicts the components of battery less power harvesting technique using solar, piezo and RF.

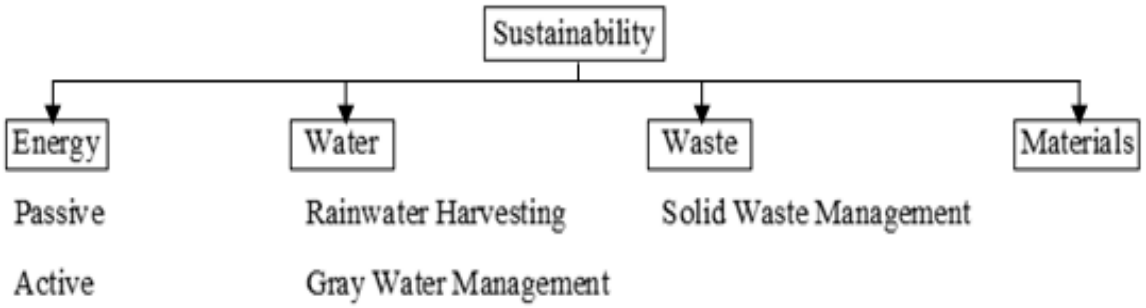

Fig -1: Flowchart on Practices of Sustainable Buildings

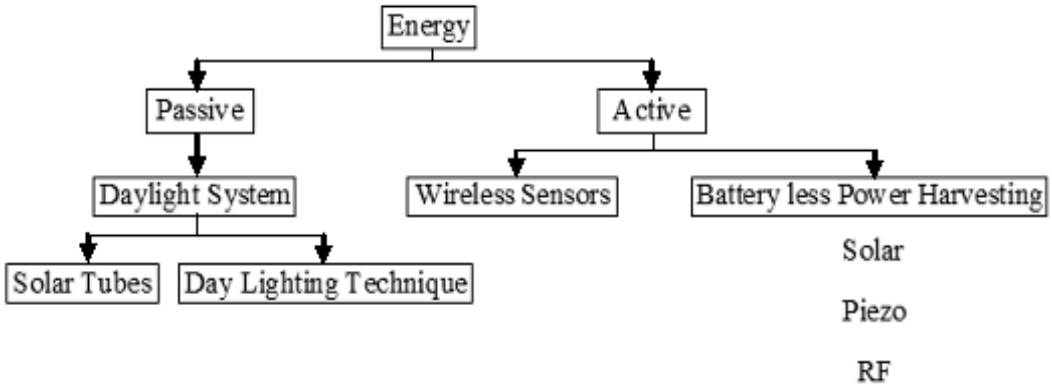

Fig -2: Flowchart on Methods of using Energy in Sustainable Buildings

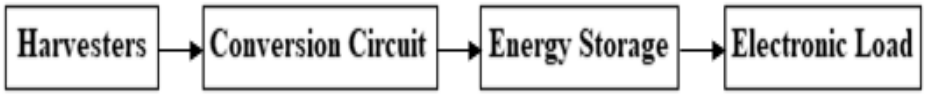

Fig -3: Components of Battery less Power Harvesting (Solar, Piezo and RF)

2.3.1 Energy – Passive Techniques

a. Building Orientation

Table -1: Building direction and access to daylight

S.No.	Direction	Access to Daylight
1	South	Can provide access to controlled day lighting
2	North	Best for day lighting
3	East & West	Hard to control direct sun light

The preferable building orientation is the longer side facing North and South whereas the shorter side facing East and West as given in **Table -1**.

b. Building Form

Long and narrow foot prints are better than square one so that the day light would penetrate into the building from all sides as mention in **Fig -4**.

c. Color

Color of ceiling must be white to reflect back the light. Light self can be used to illuminate the ceiling as much as possible is illustrated in **Fig -5**.

d. Top Lighting Technique

The different types of top lighting system are employed to bring in day light into the building. The types of top light system and its description are given in **Table -2** and **Fig -6**.

Table -2: Types of top lighting system

S.No.	Top Light System	Description
1	Clerestory	Above eye level – both light and fresh air comes inside
2	Monitor	Vertical openings in sides – single sided or two sided based on the design
3	Saw Tooth	Sloped opening in roofs provide directional effect inside the room
4	Skylight	Windows fixed in roof – directs day light inside
5	Solatube	Innovative method of day light

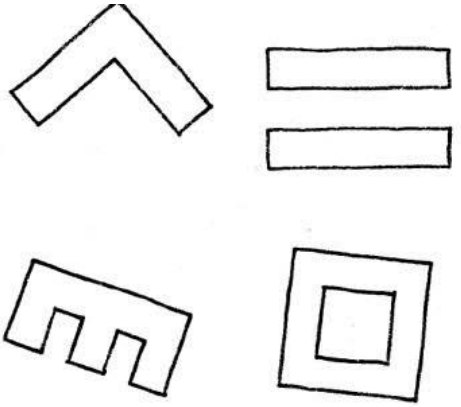

Fig -4: Examples of building foot prints with high day light access

Innovative Method of Top Lighting - Solatube Technique

Unlike artificial lighting, solatube is a innovative method of day lighting which directs sun light in a particular path, reflects several times and delivers light in to the building like an LED is given in **Fig -7** [8].

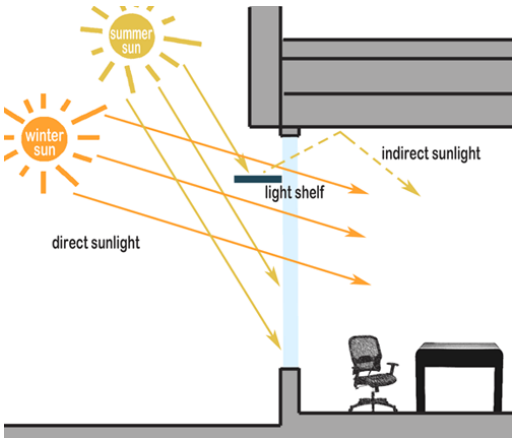

Fig -5: Illumination through light self

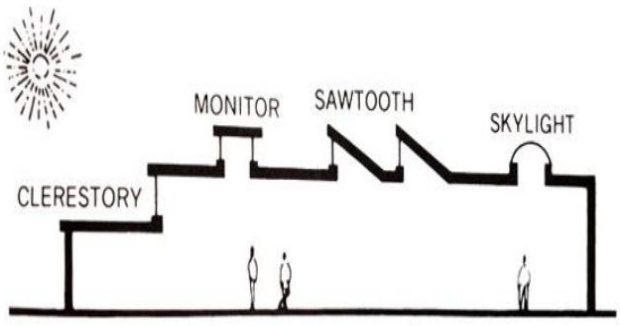

Fig -6: Types of Top Lighting system

Fig -7: Solatube technology

e. Treatment of Windows – Peroveskite Windows

It could both cool and power buildings. It can be reversibly switched between a transparent and opaque state with no degradation of its electronic properties as shown in **Fig -8**. When it is in opaque state it's able to generate electricity.

Fig -8: Perovskite window

2.3.2 Energy – Active Techniques (Wireless Sensors and Battery-less Power Harvesting)

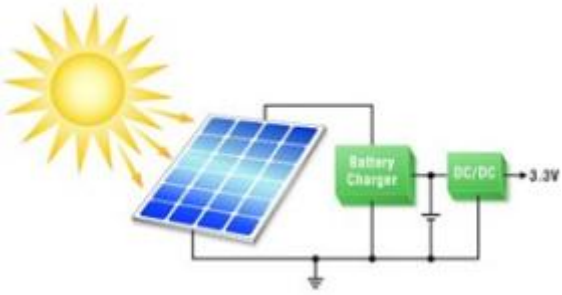

Fig -9: Solar Energy Harvesting [9]

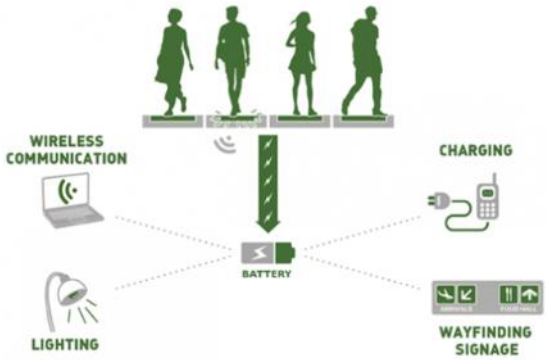

Fig -10: Piezo-electricity Energy Harvesting [10]

a. Technology

Intelligent wireless and battery less switches and sensors obtain energy from three main sources such as movement, light (solar) and radio frequency. That energy is efficient to transmit sensor data which controls lights, blinds and room temperature. The solar energy harvester will be able to obtain voltage of around 3.3V [9] is given in **Fig -9**. Whereas the piezo will harvest energy from vibration and will be able to charge mobile phones, lightings, wireless communication devices and way finding signage [10] as shown in **Fig -10**. The RF will obtain energy from RF energy source, cellular phone stations, wireless routers, RFID readers, mobile phones and RF radios [11] is given in **Fig -11**.

b. Applications

Buildings (flats, single houses, prefabs, commercial building, hospital, offices, schools and hotels) are made sustainable by employing self powered battery less wireless sensors.

c. Installation (residence)

A transmitter is connected with a receiver. In case of longer distance repeaters are used. This system can be connected to tablets, mobile and video camera to monitor and control the systems. It is used for

retrofitting, central control for light and blinds, heating control with window monitoring, provides zone regulation, window monitoring, alert messages and presence simulation.

d. Installation (industries)

It is very convenient to connect the system with existing systems. When changes are made in office space such as alteration of room structures, it is easy to connect with battery less and wireless technology.

e. Range planning

Range of transmission can be determined based on penetrating angle, absorbing material and other source of interference. As absorption increases range decreases. Wood, plaster and brick has low absorption whereas concrete and metal has high absorption.

f. Disadvantages of battery driven wireless solution

It causes pollution and needs regular replacement.

g. Advantages of batteryless and wireless system –

i. Suitable for simple and complex application.
ii. Energy efficient and economical
iii. Easy use and installation
iv. Freely positional sensors
v. Less noise and dirt
vi. Maintenance is not needed
vii. Adaptable to technical innovations
viii. Provides security systems

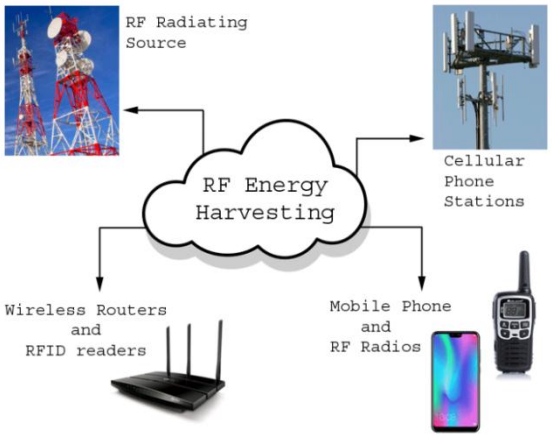

Fig -11: RF Energy Harvesting [11]

2.3.3 Water – Rain Water Harvesting

It is defined as a method of inducing, collecting, storing and conserving local surface runoff. Both small and large scale structures are used for rainwater harvesting collection and storage including water pans, tanks, reservoirs and dams as shown in **Fig -12**.

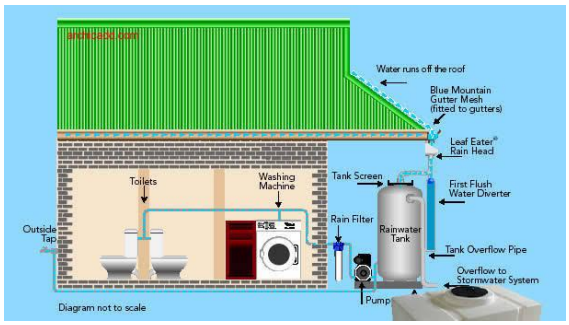

Fig -12: Rainwater harvesting system

Components of rainwater harvesting system

a. The **catchment** area is the area where the rainfall or water runoff is initially captured in roof top or ground surface.
b. **Coarse mesh** is placed at the roof top to avoid the penetration of debris
c. **Gutter** are placed at the slopes of the roof to collect the rainwater through pipes into the storage area
d. **Conduits** are the pipelines which transfers the water from catchment area to the storage tanks
e. **First-flushing** is the method of flushing away the first spell of rain as it contains surface dirt and air pollutants
f. **Filter** is to remove the pollutants and dirt from the rain water before storage which is collected from the roof. A filter unit is a chamber filled with materials to filter the dirt and debris such as charcoal water filter and sand filter
g. **Storage** has various options such as RCC, ferro-cement, polyethylene, GI sheets, etc.

2.3.4 Water – Grey Water Management System – SOAP Technique

Solar optics based active panels (SOAP) for grey water reuse and integrated thermal building (GRIT)

Procedure

a. Grey water is collected from sink, bathtubs and laundry
b. The collected water is exposed to the façade of the building which has a solar-based opto-fluidic platform (light is captured, transmitted and efficiency of water disinfection is increased)
c. The water after disinfection is circulated into the building through pipelines to heat up the floor (water is used for thermal comfort)
d. After which the disinfected water is used again for toilet flushing and laundry

2.3.5 Waste - Solid waste management

Waste management hierarchy from least favored to most favored option is given in **Fig -13**.

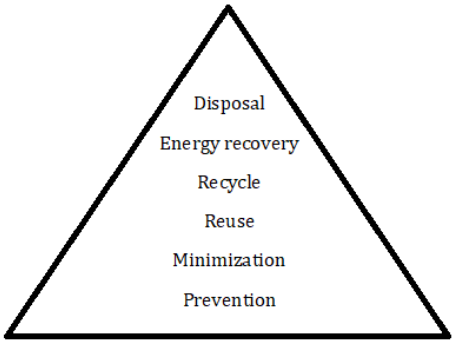

Fig -13: Waste management hierarchy from least favored to most favored option

Potential application of various types of solid waste in building applications

1. Organic wastes
   Wastes such as Baggage, rice and wheat straw and husk, coconut shell, fibers and husk Cotton stalk, Saw mill waste, ground nut shell, banana stalk and jute, sisal and vegetable residues can be used for:
   a. Particle boards, insulation boards, wall Panels, cement board and fibrous building panels
   b. Roofing sheets, bricks, coir fiber and mats
   c. Acid proof cement, reinforced composite and Polymer composites
2. Inorganic waste
   Wastes such as Coal combustion residues, steel slag, bauxite red mud, Construction debris, glass, plastic and fly ash can be used for:
   a. Cement, bricks, blocks and tiles
   b. Paint, aggregate, concrete and wood
   c. Substitute products and ceramic products
   d. Mineral filler in asphalt paving mixtures, soil stabilization and structural fill
   e. Glass used in place of aggregates
   f. Many uses for recycled plastics such as fencing, furniture and outdoor landscape elements.
3. Construction waste
   Wastes such as recycled concrete, wood waste, soil, rubble, asphalt and metals can be used for:
   a. Aggregate base for pavements, sub base for new pavements, shoulders, base course for foundations and backfill for utility trenches.
   b. Wood fibers used for fiberboard products for various applications such as sub flooring, sheathing and structures for insulation and damping of sound.
   c. Soil used as aggregates
   d. Asphalt used for paving
   e. Metals sold as scraps for re-use 2014and re-cycling

Solid waste management for energy resource

Raw materials such as agriculture waste, municipality waste, plant material, sewage, green waste or food waste is used to produce, biogas. The raw materials are mostly collected from kitchen and toilets and dumped in the pits. Due to anaerobic digestion biogas and digestate is produced. Biogas releases heat, power and bio-methane which are used for transportation fuel and gas grid. Digestate is used for fertilizer, bedding and compost [12]. The biogas production and results are illustrated in **Fig -14**.

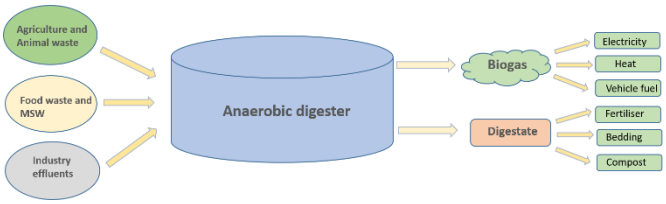

Fig -14: Biogas production and results

2.3.6 Materials

Characteristics of sustainable building materials

a. Health – the material used should not cause any harm to the health of the people
b. Environment impact – the materials used should have less impact on the environment for its entire lifespan (pollution free materials)
c. Economical – sustainable materials are costlier than usual ones, but provides good life, durability and reduces maintenance cost
d. Aesthetics –the material must also provide pleasing look to the user to raise the quality of life
e. Source – locally available materials must be used which reduces transportation cost and damages
f. Renewable and reusable – the source of the materials must be renewable and must be biodegradable
g. Reduction of construction waste – minimal construction waste during installation reduces the need for landfill space and also provides cost saving

Examples of sustainable materials

The various materials used for sustainable buildings and its application in various parts of the building are given in **Table -3**.

Table -3: Examples of sustainable materials and its usage

S.No.	Materials	Uses
1	Straw bale	Wall construction
2	Grass-crete, ash-crete and timber-crete	Pavement and wall construction
3	Rammed earth	Wall construction
4	Hemp-crete	Wall construction
5	Bamboo	Wall, bridge and roof construction
6	Wood	Can be utilised in all parts of building
7	Recycled plastic	Wall construction

Phases of the building material life cycle and factors of sustainable material

1. Pre-building phase (manufacturing)
    a. Waste reduction
    b. Pollution prevention
    c. Recycled content
    d. Use of natural material
    e. Embodied energy reduction
2. Building phase (use)
    a. Energy efficiency
    b. Waste treatment
    c. Renewable resource
    d. Longer life
    e. Use of non-toxic materials
    f. Reduction in construction waste
3. Post- building phase (disposal)
    a. Reusable
    b. Recyclable
    c. Biodegradable

2.4 Impacts or Benefits of Sustainable Buildings

The impacts and benefits of sustainable building is given in **Table -4**[13].

Table -4: Impacts or benefits of sustainable buildings in various typologies of buildings

S. No.	Sustainable Buildings	Impacts or Benefits
1	School	20% best test performance
2	Hospital	Two and half days earlier discharge
3	Retail	Increase in sales per sq. ft.
4	Factory	Increase productivity
5	Office	2% to 16% productivity increase
6	Residence	Reduce demand on various resources

3. CONCLUSION

Thus in order to make the building sustainable the smart home automation system is employed by using energy harvesting system, solid waste management system, rain water harvesting system and gray water management system. The sources of energy harvesting system include solar energy, piezo-electricity and radio frequency (RF) which harvest enough energy to power up the wireless sensors used in smart home automation system. The hybrid energy harvester is better than a single energy harvester that aids in powering the sensors wirelessly when any one of the source goes down than the other making the system sustainable.

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