# THE ROLE PLAYED BY GREEN BUILDINGS IN THE ACHIEVEMENT OF SUSTAINABLE DEVELOPMENT GOALS 3, 7 & 8

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## INTRODUCTION

Highlighting the benefits of green buildings, which is inexhaustive, shows that there are a lot of similarities between what green buildings aim to achieve and the sustainable development goals. Having a closer look at these benefits shows that the same objective targeted to be achieved by the sustainable development goals which include good health and well-being, affordable and clean energy, decent work, and economic growth, amongst others, is achieved when green building principles and practices are applied on buildings and other related projects.

Overall, the end result of all these, is a better life and a more sustainable future for us all.

## THE SUSTAINABLE DEVELOPMENT GOALS

The Sustainable Development Goals (SDGs) define the world we want and apply to all nations of the world. It is also referred to as the Global Goals and was adopted by all United Nations Member States in 2015 as a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity by 2030. It is made up of 17 goals with 169 targets, that all UN Member States have agreed to work towards achieving by the year 2030.

The SDGs aim to be relevant to all countries, poor, rich, and middle-income, with a view to promoting prosperity while protecting the environment and tackling climate change. They have a strong focus on improving equity to meet the needs of women, children, and disadvantaged populations so that no one is actually left behind.

The agenda builds on the Millennium Development Goals (MDGs) which were 8 goals that UN Member States signed in September 2000 to achieve targets to combat poverty, hunger, disease, illiteracy, environmental degradation, and discrimination against women by 2015.

The Sustainable Development Goals are designed to be a blueprint for achieving a better and more sustainable future for all. Though the goals are broad and interdependent, on July 6, 2017, a UN Resolution adopted by the General Assembly made the SDGs more actionable. The resolution identifies specific targets for each goal,

along with indicators that are being used to measure progress toward each target. The year by which the target is meant to be achieved is usually between 2020 and 2030.

## The 17 Sustainable Development Goals


Culled - https://www.unicef.org/georgia/sustainable-development-goals

## CONTRIBUTION OF GREEN BUILDINGS TOWARDS ACHIEVEMENT OF SUSTAINABLE DEVELOPMENT GOAL 3- GOOD HEALTH & WELL-BEING

Sustainable Development Goal 3 aims to increase the health and well-being of people of all ages. One target of this goal is to substantially reduce by 2030 the number of deaths and illnesses from hazardous chemicals, air, water, and soil pollution and contamination.

The LEED V4 rating system, on the other hand, has provided several requirements to ensure the health and well-being of building occupants, contributing to the attainment of sustainable development goal 3. One such approach includes Internal environmental quality requirements for LEED projects.

## Internal Environmental Quality (IEQ) Requirements for LEED Projects

With respect to internal environmental quality, we would be looking at the following:

## Minimum Indoor Air Quality Performance:

Poor indoor air quality can irritate the eyes, nose, and throat, cause shortness of breath, aggravate asthma and other respiratory conditions, and affect the heart and cardiovascular system. Breathing polluted air for long periods of time can cause more serious problems. To curb this problem, LEED has established the minimum standards for indoor air quality performance for green buildings, with the intent of contributing to the comfort and well-being of building occupants. This is a mandatory requirement for LEED projects and the whole objective is to ensure compliance with ASHRAE 62.1 standards. ASHRAE 62.1 identifies minimum ventilation rates for the IEQ prerequisite baseline. The climate and local outdoor air quality will help determine what type of ventilation is appropriate for the project. An area with high outdoor air pollution would have to use an active/mechanical ventilation system as against a passive ventilation system, to avert the health dangers and meet the demands of the high level of filtering that would be required. Project teams are required to review the ASHRAE standard and ensure their projects meet or exceed the requirements.

## Environmental Tobacco Smoke Control:

In the U.S. alone, smoking tobacco is related to over 400,000 premature annual deaths. Furthermore, the average life expectancy of a smoker is 10 years less than that of a nonsmoker. In addition to nicotine, cigarettes contain about 600 ingredients that form over 7,000 compounds when burned, of which at least 69 are known to be carcinogenic. Secondhand smoke exposes non-smokers to the same toxins, increasing the number of people subject to health risks from smoking. The intent of LEED with respect to this is to prevent or minimize exposure of building occupants, indoor surfaces, and ventilation air distribution systems to environmental tobacco smoke (ETS). This is actually a mandatory requirement for LEED projects. For commercial buildings, Smoking is completely prohibited inside the building, while outside the building, smoking is also prohibited as well, except for designated smoking areas that must be located 25ft from the building entrance, air intake, and operable windows. For residential buildings, the options include prohibiting smoking inside the building or allowing smoking within ETS rooms that are separately ventilated and have negative pressure and exhaust. It is important to note the ventilation and exhaust can’t connect to the ventilation and exhaust from non-smoking rooms.

Typical smoking shelter, culled - http://www.premierlimited.co.uk/3-fully-installed-smoking-shelter-codesshbs3-i472.html

## Enhanced Indoor Air Quality Strategies:

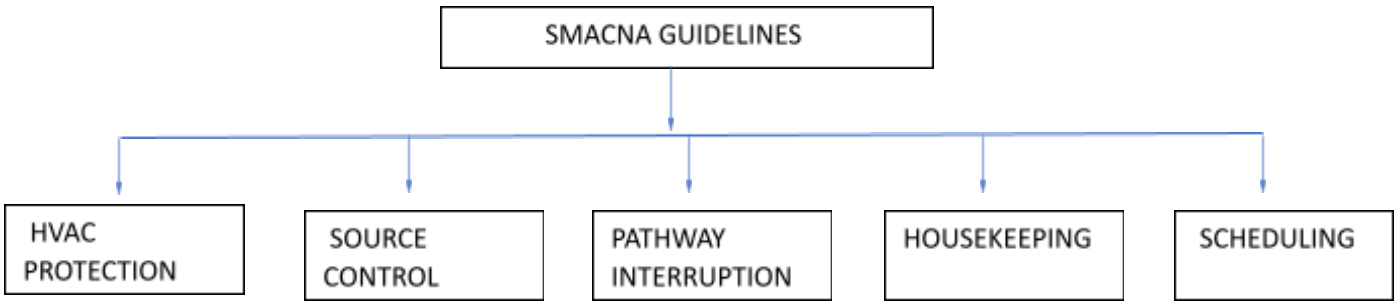
This actually improves the air quality more than the minimum indoor air quality performance baseline. This requirement is about controlling the pollutants that affect buildings arising from people, cars, or equipment. It achieves this through enhanced indoor air quality strategies and additional enhanced indoor air quality strategies. Enhanced indoor air quality strategies deal with entryway systems, interior cross-contamination prevention, filtration, natural ventilation design calculations, and mixed-mode design calculations. Additional enhanced indoor air quality strategies deal with exterior contamination prevention, increased ventilation, carbon dioxide monitoring, additional source control monitoring, and natural ventilation room-by-room calculation.

## Using Low-Emitting Materials for Projects:

The intent of LEED V4 in regards to this, is to reduce concentrations of chemical contaminants that can damage air quality, human health, productivity, and the environment, while in so doing limiting occupant exposure to harmful chemicals. These contaminants which are measured as VOC and emissions must comply with stated limits set by the prescriptive product category approach or budget calculation method. The following materials are usually looked into in this whole process while ensuring compliance, and they include Interior paints and coatings, interior adhesives and sealants, flooring, composite wood, ceilings, walls, thermal, and acoustic insulation, furniture, and exterior applied products which are applicable to healthcare and school projects only.

## Construction Indoor Air Quality Management Plan:

The intent of LEED V4 regarding this is to promote the well-being of construction workers and building occupants by minimizing indoor air quality problems associated with construction and renovation. The plan complies with SMACNA guidelines, which address indoor air quality in five major areas including HVAC protection, source control, pathway interruption, housekeeping, and scheduling.




## Indoor Air Quality Assessment:

The sole intent of indoor air quality assessment for LEED projects is to establish better quality indoor air in the building after construction and before occupancy. This is

designed to verify that the air is clean before people regularly occupy the building. It achieves this through flush-out and air quality testing.

Air flushing is a technique performed to clean the air after construction just prior to building/office occupancy to remove pollutants such as formaldehyde and other volatile organic compounds (VOCs).

Air quality testing is done in areas with the least ventilation and the highest concentration of VOCs, i.e., the worst-case scenario. At least one test per floor must be completed, and at least one location per ventilation system for each occupied space type. Testing locations occur in the breathing zone, between 3 and 6 feet (900 and 1,800 millimeters) above the floor. Once the testing is complete, an IAQ report is generated for documentation.

Air Flushing

Flush out of an office building prior to occupancy, Culled - http://www.iaqphilippines.com/air-flushing/

## Thermal Comfort:

Thermal comfort can affect mood, performance, and productivity. It is provided in the body through homeothermy, the balancing of heat gains and losses to maintain the body's core temperature within its narrow range, 36-38 °C [97-100 °F], which is regulated by the hypothalamus.

LEED intends to promote occupants' productivity, comfort, and well-being by designing for high-quality thermal comfort and providing occupant controls. For international projects, thermal comfort must comply with ASHRAE 55 or ISO/CEN standards. Also,

thermal comfort controls are required to serve at least 50% of building occupants and 100% of all multi-occupant spaces.

## Interior Lighting:

Common health effects associated with poor lighting include headache, eye strain, neck/shoulder strain (when straining to see items because of poor lighting), and depression (in the case of insufficient or gloomy lighting).

The intent of LEED in regards to this, is to promote occupants' productivity, comfort, and well-being by providing high-quality lighting. One of which includes ensuring 90% of the building occupants have task lighting, as well as the building having 3-way lighting controls for all shared multi-occupant spaces. Also with respect to lighting quality, projects must meet 4 of the following strategies which include ensuring that recessed fixtures are all glare-free recessed luminaires in regularly occupied spaces, the entire project must have a CRI of greater than 80 except for special uses, 75% of the connected load must have a lamp life greater than 24,000 hours, less than 25% of the connected load can be direct-only in regularly occupied spaces for indirect luminaires, and also for walls/ceilings/floors reflectance levels should be approximately 80% on the ceiling, 50% on walls and 20% on floors. If furniture is included in the scope, the average surface reflectance must be 45% for work surfaces and 50% for movable partitions. For illuminance strategies, for at least 75% of regularly occupied floor area, ceilings or walls should have a 1 to 10 threshold to achieve occupant comfort.

Task Lighting, Culled - https://cdn3.volusion.com/ps2ty.k63d4/v/vspfiles/photos/REVO-2.jpg?v-cache=1512514951

## Acoustic Performance:

Exterior noise intrusion particularly in urban areas, loud or repetitive exterior noises can be a source of stress and a risk factor for certain health outcomes. Studies show that individuals exposed to traffic noise have a higher risk for diabetes, stroke, and heart attack, and those exposed to road traffic and aircraft noises have a higher risk for hypertension. In addition, exposure to noise can lead to reduced reaction time and increased levels of annoyance. Electronics, HVAC systems, mechanical equipment, and other noise-emitting office devices, as well as occupants themselves, can be sources of indoor noise. As offices and workspaces are increasingly designed to promote employee interaction, occupants can experience decreased levels of privacy and acoustic comfort, especially when users with different job types share a space. Office noise can lead to decreased productivity, especially in open-plan offices where aural distractions and interruptions from other employees are frequent. Additionally, studies show that exposure to noise generated within the building can lead to reduced concentration and mental arithmetic performance, and increased distraction due to reduced speech privacy.

LEED makes it mandatory for schools to meet acoustic performance with respect to HVAC background noise, exterior noise, and reverberation time. HVAC systems are to have a maximum of 40 decibels in classrooms and learning areas as a prerequisite but must be reduced to 35 decibels to be rewarded with credit points. High-noise sites are defined as having a peak-hour noise level of 60 DB. Projects at least one-half mile (800 meters) from any significant noise source (e.g., aircraft overflights, highways, trains, industry) are exempt, otherwise, project teams are required to design acoustic treatments and other measures to minimize noise intrusion from exterior sources. In addition, classrooms and other core learning spaces are to be designed to control sound transmission between spaces.

With respect to reverberation times, the LEED V4 rating system is recommended as a prerequisite for specifying materials with a Noise Reduction Coefficient (NRC) of 0.70 or higher. Compliance can be met by providing 100% acoustical ceiling tiles excluding areas covered by diffusers and lights. Another approach would be to confirm through calculations that rooms are designed to achieve reverberation time guidelines stated in ANSI Standard S12.60-2010. Another path to this requires calculations demonstrating the achievement of recommended reverberation times for classrooms and core learning spaces described in the NRC-CNRC Construction Technology Update No. 51, Acoustical Design of Rooms for Speech.

For sound reinforcement masking, the design levels must not exceed 48 dBA. Also, care needs to be taken to ensure that loudspeaker coverage provides uniformity of plus or minus 2dBA and that speech spectra are effectively masked.

## Other ways in which LEED promotes the health and well-being of people include:

## Environmental site assessment for schools and health care projects:

This is a mandatory requirement for schools and healthcare only, which are what you would call sensitive types of occupancy. The intent is to protect the health of vulnerable populations by ensuring that the site is assessed for environmental contamination and that any environmental contamination has been remediated. The assessment shall cover soil, groundwater, and surface water. A phase one only, or a phase one and two environmental assessment is usually carried out depending on the situation of the site, after which remediation is carried out.

## Building Product Disclosure and Optimization of Material Ingredients for Green Building Projects:

LEED actually rewards projects that declare all product/material ingredients more than 0.1% by weight and gives them even more points if they can prove that they are avoiding some of the most hazardous chemicals, as determined by several governmental lists. It approaches this through material ingredient reporting, material ingredient optimization, and product manufacturer supply chain optimization.

Material Ingredient Reporting is based on using at least 20 permanently installed products that provide a chemical inventory through one of a variety of third-party programs, such as an HPD, a Manufacturer's Inventory that must meet a number of criteria, or Cradle to Cradle v2 Silver certification. This will require manufacturers to have documentation on the whole product preparation and to use a standard program to inventory the name, chemicals, attributes, structures, and number of ingredients in the product. The manufacturer inventory involves publishing Chemical Abstract Service Registration Numbers (CASRN) for all ingredients in the product: some ingredients may be kept proprietary, but their hazard potential based on the Green-Screen benchmarking system must be disclosed. This inventory is very similar to the HPD program. HPD are a standard format for transparent disclosure of building product ingredients and associated hazards. HPDs were created by the Health Product Declaration Collaborative and are mainly used in North America. An HPD has two parts, an inventory of ingredients and an assessment. The HPD reviews the ingredients against an authoritative list. HPDs build on and incorporate the data from the EPD but go on to combine it with trustworthy and verifiable measures of ingredients that impact ecotoxicity and human toxicity. As such, it creates a disclosure document that truthfully indicates the toxicity impact of a product on the people who live with it, and the natural environment that it exists within. An HPD informs users how the product affects their bodies.

Material Ingredient Optimization involves using at least 25% by cost of products that have assessed and optimized their material ingredients against preapproved USGBC programs such as Green-Screen v1.2 Benchmark, Cradle to Cradle v2 Gold or Platinum Certification.

Product Manufacturer Supply Chain Optimization involves using new building products for at least 25% at the cost of the total value of the permanently installed fixtures that are sourced from manufacturers that engage in validated and robust safety, health hazard, and risk programs, which at a minimum document at least 99% by 166 weight the ingredients used to make the material or product.

## Furniture & Medical Furnishings for Health Care Projects:

The intent of LEED in regard to this is to enhance the environmental and human health performance attributes associated with freestanding furniture and medical furnishings. It rewards projects that use at least 30% or 40%, by cost, of all freestanding furniture and medical furnishings (e.g., mattresses, foams, panel fabrics, cubicle curtains, window coverings, other textiles) that meet the criteria in one of the following which includes minimal chemical content, testing and modeling of chemical content, and multi-attribute assessment of products.

Minimum chemical content requires all components that constitute at least 5% by weight of furniture and medical furnishing should contain less than 100 points per million of at least 4 out of the following chemicals which include formaldehyde, heavy metals, chromium in plated finishes, stain and non-stick treatments derived from perfluorinated compounds, and added antimicrobial treatments.

Testing and modeling of chemical content requires all components of a furniture or medical furnishing assembly, including textiles, finishes, and dyes, must contain less than 100 parts per million (ppm) of at least 2 of the following chemicals which include formaldehyde, heavy metals, chromium in plated finishes, stain and non-stick treatments derived from perfluorinated compounds, and added antimicrobial treatments. New furniture or medical furnishing assemblies must be in accordance with the ANSI/BIFMA standards, and you have to model the test results using the open plan, private office, or seating scenario in ANSI/BIFMA M7.1.

Multi-attribute product assessment requires using products that meet at least one of the defined criteria. Each product can receive credit rewards for each criterion met. The scope of any EPD must be at least cradle to gate. Product self-declaration covering at least cradle to gate scope includes EPDs, materials reuse, recycled content, take-back program, biobased materials, and certified wood.

## PBT Source Reduction - Mercury, Lead, Cadmium, and Copper in Health Care Projects:

Inhalation of mercury vapor can produce harmful effects on the nervous, digestive, and immune systems, lungs, and kidneys, and may be fatal. The inorganic salts of mercury are corrosive to the skin, eyes, and gastrointestinal tract, and may induce kidney toxicity if ingested. Exposure to high levels of lead may cause anemia, weakness, and kidney and brain damage. Very high lead exposure can cause death. Lead can cross the placental barrier, which means pregnant women who are exposed to lead also expose their unborn children. Lead can damage a developing baby's nervous system. Occupational exposure to cadmium can lead to a variety of adverse health effects including cancer. Acute inhalation exposure (high levels over a short period of time) to cadmium can result in flu-like symptoms (chills, fever, and muscle pain) and can damage the lungs. Long-term exposure to copper can cause irritation of the nose, mouth, and eyes and also result in headaches, stomach aches, dizziness, vomiting, and diarrhea. High intake of copper may cause liver and kidney damage and even death.

With respect to the use of mercury, LEED has made it a mandatory requirement to reduce mercury-containing products and devices and mercury release through product substitution, capture, and recycling. It provides a corresponding credit reward that requires specifying and installing fluorescent lamps with both low mercury content and long lamp life.

With respect to lead, fittings and soldering need to be addressed, roofing and flashing must be lead-free, as well as all paints. Electrical wire has to have a minimum amount of lead as well.

For cadmium, specify no use of interior or exterior paints containing intentionally added cadmium. Green Seal-certified paint is required to contain no cadmium.

For copper pipe applications, reduce or eliminate joint-related sources of copper corrosion.

## CONTRIBUTION OF GREEN BUILDINGS TOWARDS ACHIEVEMENT OF SUSTAINABLE DEVELOPMENT GOAL 7 - AFFORDABLE & CLEAN ENERGY

The objective of sustainable development goal 7 is to ensure access to affordable, reliable, sustainable, and modern energy for all.

LEED V4 is contributing towards the achievement of this goal by driving energy efficiency and renewable energy use in green buildings. Energy efficiency results in the reduction of energy use for space heating and/or cooling and water heating: Reduced electricity use for lighting, office machinery, and domestic-type appliances: Lower maintenance requirements: Improved comfort: And enhanced property value. Again, renewable energy is a clean energy source that preserves and sustains the environment and ecosystem, while at the same time having a far reduced cost as compared to energy sourced from fossil fuels. Green building structures can efficiently use renewable energy which in the long run helps in cutting the overall cost of running the building. Another benefit of using renewable energy is that it produces no carbon emissions, which means it has minimal impact on the planet. For example, the International Renewable Energy Agency (IRENA) suggests home solar systems in Africa can provide households with electricity for as low as $56 a year – much cheaper than energy from diesel or kerosene. Energy efficiency coupled with local renewable sources also improves energy security.

## Energy Efficiency in Green Buildings

Under energy efficiency, we would examine minimum energy performance, optimizing energy performance, and energy metering for green buildings.

## Minimum Energy Performance:

It is a mandatory requirement in the LEED V4 rating system for green buildings to reduce the environmental and economic harms of excessive energy use by achieving a minimum level of energy performance for buildings and their systems. Three different approaches are used to achieve this: whole building energy simulation, ASHRAE 50% advanced energy design guide, and advanced buildings core performance guide.

For whole building energy simulation, projects need to achieve a 5% improvement for new buildings, 3% improvement for renovations, and 2% for core and shell projects based on energy costs and with respect to the baseline building performance rating that is calculated using the updated ASHRAE 90.1-2010 standard. A computer simulation model is used for the entire building. Projects must comply with the mandatory provisions of ASHRAE 90.1-2010 and include all energy costs with the building project. The percent energy savings is calculated excluding any savings from renewable energy systems.

The ASHRAE 50% Advanced Energy Design Guide is a prescriptive approach with different guides for different types of buildings. For example, offices less than 100,000 square feet are required to use the ASHRAE Advanced Energy Guide for Small to Medium Office Buildings. There are other guides for medium to large big-box retail, K-12 schools, and large hospitals. Projects must comply with the applicable criteria based on the building's specific climate zone.

Advanced Buildings Core Performance Guide is used for buildings less than 100,000 square feet (9,290 meters). Healthcare, warehouses, and lab projects are ineligible for this option.

## Optimizing Energy Performance:

Whole building energy simulation and ASHRAE Advanced Energy Design Guide are the two approaches used by LEED to optimize energy performance.

Whole-building energy simulation allows energy savings beyond the 5% prerequisite for new buildings, up to a maximum of 50%.

ASHRAE advanced energy design guide is the prescriptive path that can also be used to optimize energy performance, though projects using this are rewarded with lower credit points as compared to the whole building energy simulation approach for LEED projects. Projects are required to follow the appropriate ASHRAE design guide based on the project type and climate zone. This also requires that the project must have earlier achieved the Minimum Energy Performance Prerequisite requirement using the ASHRAE design guide as well.

## Energy Metering:

The whole idea behind energy metering is to measure and track ongoing energy efficiency in order to ensure its sustenance. Energy metering is divided into building-level energy metering and advanced-level energy metering.

Building-level metering is a mandatory requirement for LEED projects and involves Installing new or using existing building-level energy meters, or submeters that can be aggregated to provide building-level data representing total building energy consumption (electricity, natural gas, chilled water, steam, fuel oil, propane, biomass, etc.). Utility-owned meters capable of aggregating building-level resource use are acceptable. The project building must be separately metered from other buildings or structures, even if they are owned by the same party. Projects also are mandatorily required to share the data with the USGBC for a 5-year period beginning on the date the project accepts LEED certification or typical occupancy, whichever comes first. At a minimum, energy consumption must be tracked at one-month intervals, which is pretty easy since most electric bills occur in monthly cycles anyway. Project teams can either send their data to the USGBC when requested or be proactive and report online through the EPA's Energy Star Portfolio Manager program.

Advanced energy metering involves providing sub-meters for individual energy end uses that represent 10% or more of the total annual consumption of the building, added

to the initial mandatory whole building energy meter. These systems normally include Primary HVAC systems, Secondary HVAC systems, Lighting, Plug loads, and Elevators. The data has to be gathered at least hourly and be able to communicate that data remotely. All of the data must be stored for at least 36 months. Submeters are important, because, without detailed feedback, problems are going to cost extra money and extra time to detect and fix. A whole building energy meter is a good start, but it can only tell you yes, or no that your building is operating as designed. If your building is consistently exceeding predicted usage, how will you know what system to adjust? Submeters will tell you exactly where the excess occurring.


*Watt-Hour Meter*

Typical Energy Meter, Culled - https://www.elprocus.com/watt-hour-meter-circuit-working-with-microcontroller/

## Renewable Energy Use in Green Buildings

LEED V4, on the other hand, encourages the use of renewable energy in buildings by awarding credit points to projects that obtain a certain percentage of their energy from renewable sources. Its sole intent is to reduce the environmental and economic harms associated with fossil fuel energy by increasing the self-supply of renewable energy.

Onsite renewable energy systems offset building energy costs and reduce GHG emissions.

The renewable energy produced is expressed as a percent of the annual energy cost. For projects that fail to carry out an energy model, the Commercial Building Energy Consumption Survey (CBECS) database can be used to estimate the annual energy use and cost.

When considering eligible systems, it is important to note that some biofuels that have high GHG potential or toxicity potential cannot be included, and they include burning trash, forest biomass other than mill residue, wood covered with paints and coatings, preserved wood, such as pressure-treated lumber.

Eligible on-site systems used for LEED projects include Photovoltaic systems, wind energy systems, solar thermal systems, biofuel-based electrical systems, geothermal heating systems, geothermal electric systems, low-impact hydroelectric systems, and wave and tidal power systems. It is usually best and most advisable for the system to be oversized to create a safety net that allows it to become a potential power supplier to your local energy provider. This is called net metering and allows the system to become a small profit center.

## **Photovoltaic Systems**:

Solar photovoltaic systems feature solar cells that convert sunlight into electricity. The PV cell consists of one or two layers of a semi-conducting material such as silicon. When sunlight falls on the cell, an electric field is created across the layers, causing electricity to flow. The greater the light intensity on the solar cell, the higher the voltage of electricity.

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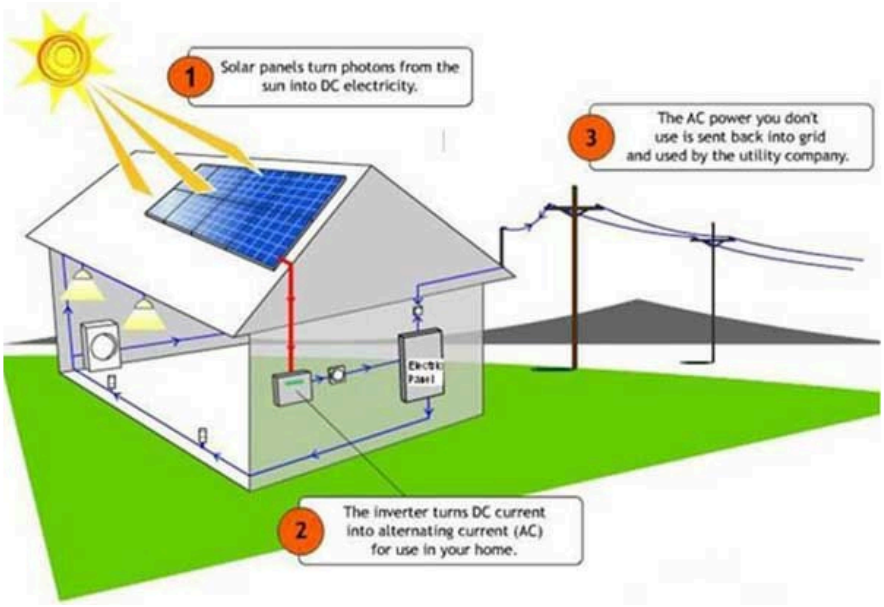
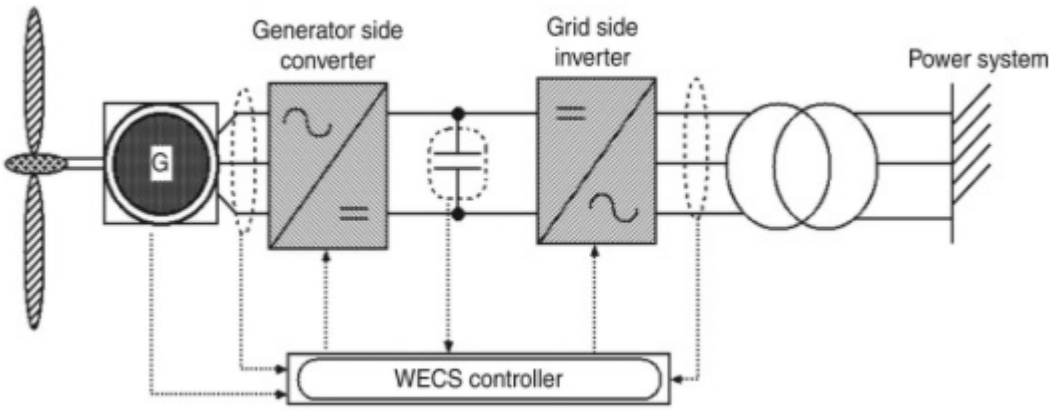


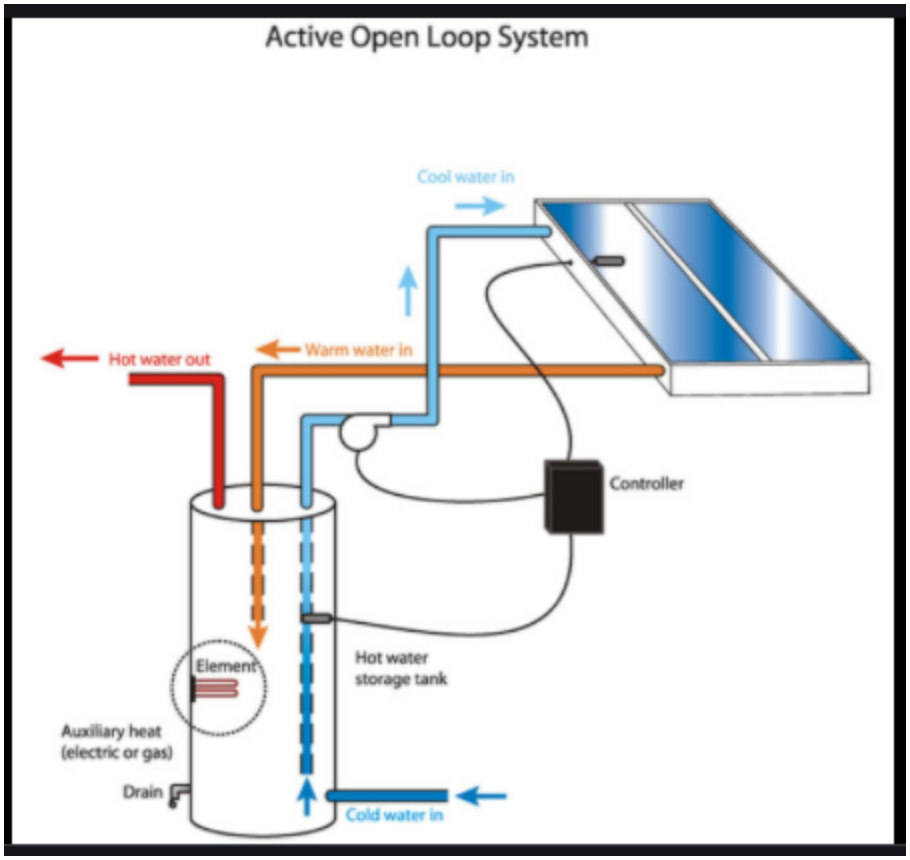

https://www.architectureanddesign.com.au/suppliers/k2solar/understanding-solar-photovoltaic-systems

**Wind Energy Systems**: Wind energy is an alternative to fossil fuels. It is plentiful, renewable, widely distributed, clean, low-cost, produces no emissions during operation, and uses a tiny land area. The effects on the environment are generally less problematic than those from other conventional power sources.




Culled - https://www.sciencedirect.com/topics/engineering/wind-energy-conversion-system

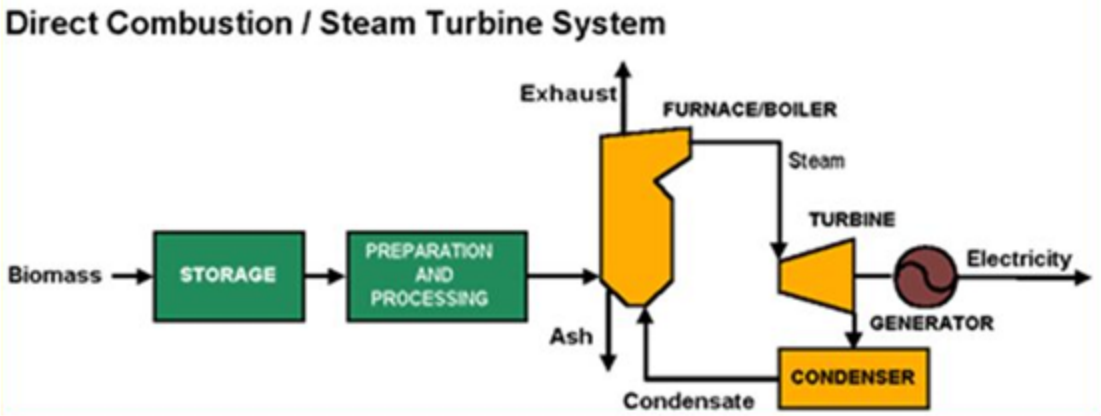
**Solar Thermal Systems**: A solar thermal energy system harnesses solar energy to generate thermal energy for use in industry, residential, and commercial sectors.




Culled-https://www.inbalanceenergy.co.uk/articles/solar_thermal_system_design.html

## Biofuel-Based Electrical Systems:

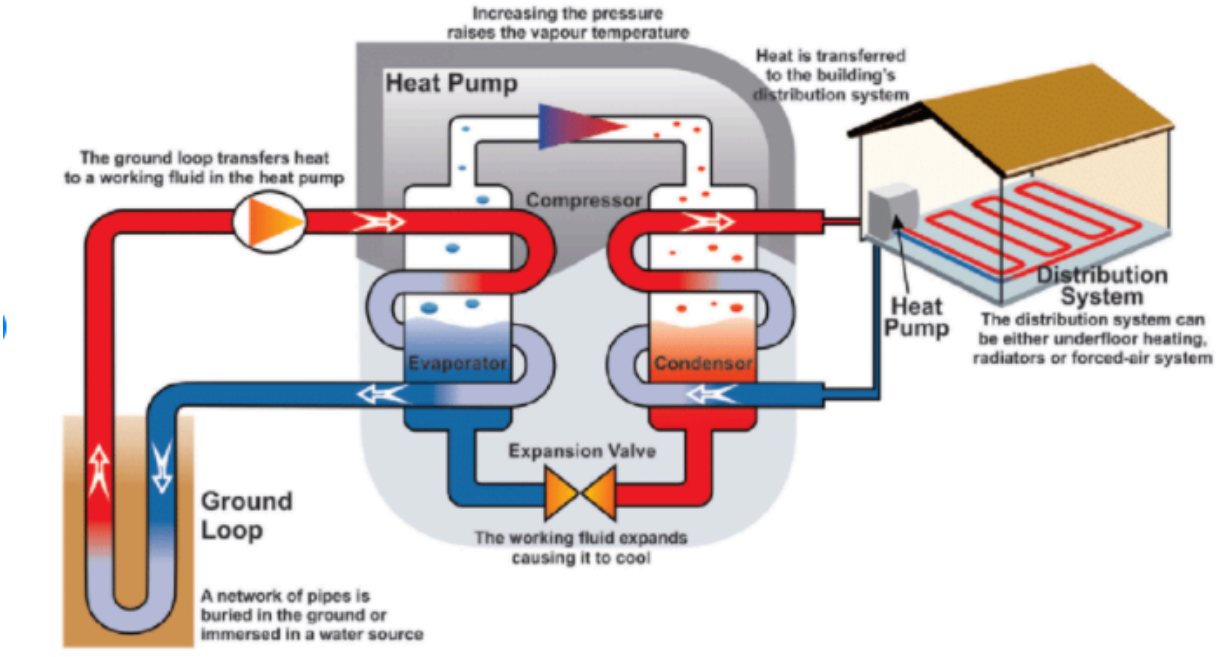
Biomass is used for facility heating, electric power generation, and combined heat and power. The term biomass encompasses a large variety of materials, including wood from various sources, agricultural residues, and animal and human waste. It can be converted into electric power through several methods. The most common is the direct combustion of biomass material, such as agricultural waste or woody materials.




In a direct combustion system, processed biomass is the boiler fuel that produces steam to operate a steam turbine and generator to make electricity.

Culled- https://www.wbdg.org/resources/biomass-electricity-generation

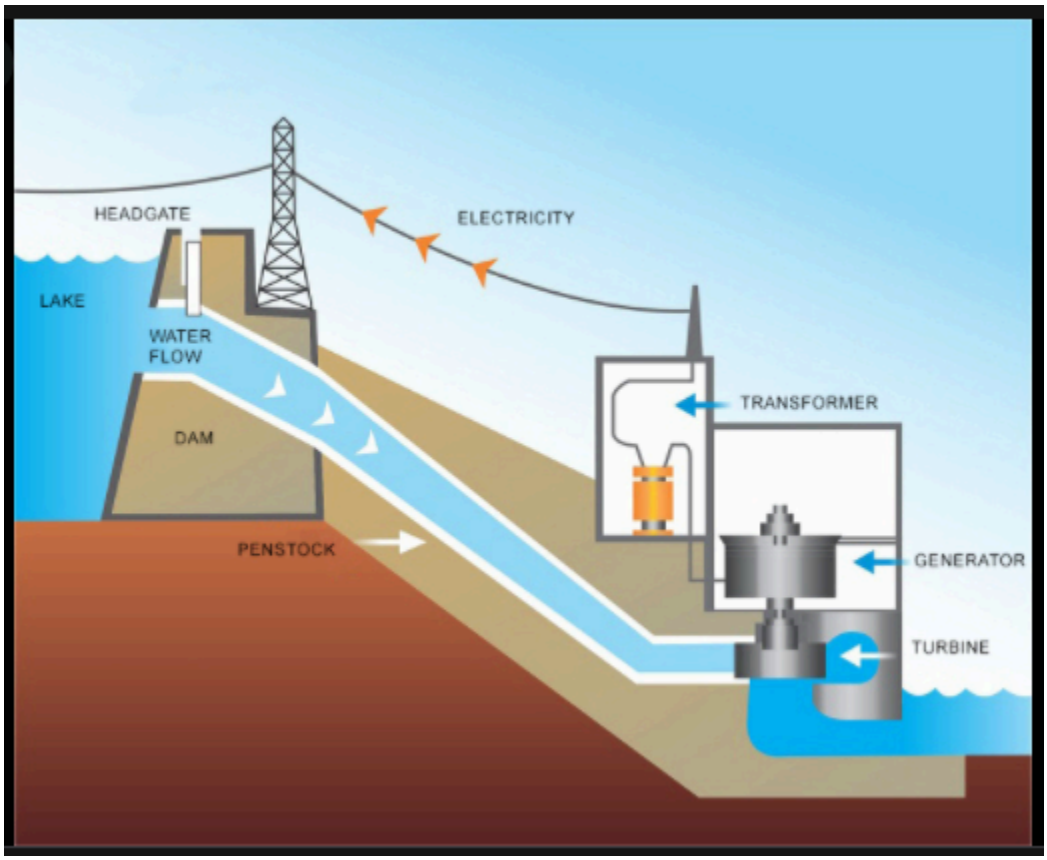
**Geothermal Heating Systems**: A geothermal heat pump (GHP) or ground source heat pump (GSHP) is a central heating and/or cooling system that transfers heat to or from the ground, often through a vapor-compression refrigeration cycle. It uses the earth all the time, without any intermittency, as a heat source (in the winter) or a heat sink (in the summer). This design makes the most of the moderate temperatures in the ground to boost efficiency and reduce the operational costs of heating and cooling systems and may be combined with solar heating to form a geo-solar system with even greater efficiency. They are also called geo-exchange, earth-coupled, earth energy systems.




Geothermal heat pump schematic (in heating mode).

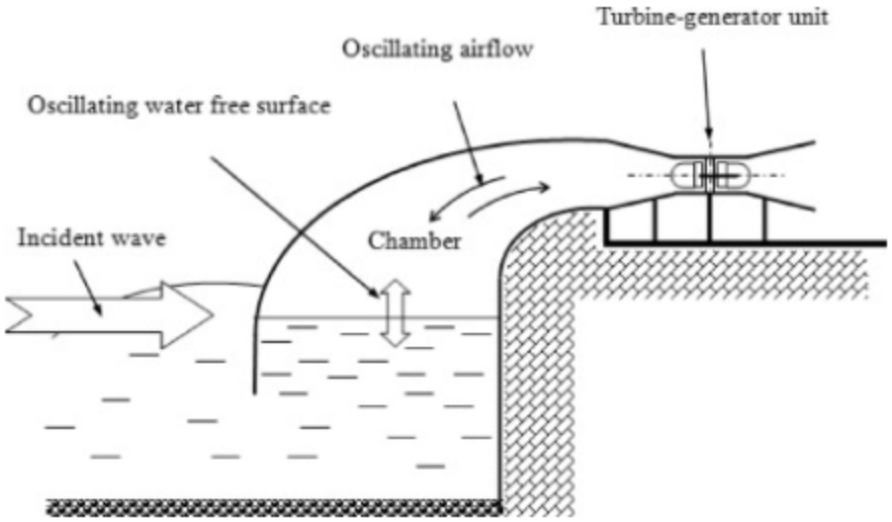
Culled-https://www.researchgate.net/figure/Geothermal-heat-pump-schematic-in-heating-mode_fig2_316919670

**Low Impact Hydro Electric Systems**: Hydroelectric power uses the force of flowing water to create renewable energy. The flow through rivers turns turbines that produce electricity.




Culled - Low Impact Hydro Electric Systems pictures - Google Search

**Wave & Tidal Power Systems**: The endless motion of the sea surface in the form of wind constitutes a source of energy which is known as wave energy. Extraction of energy from waves tends to be more efficient than direct collection of power from wind since the wave energy is concentrated through the interaction of the wind and free ocean surface.



Wave Energy Conversion System

Culled- https://electricalvoice.com/ocean-energy-wave-tidal-energy-otec/

## CONTRIBUTION OF GREEN BUILDINGS TOWARDS THE ACHIEVEMENT OF SUSTAINABLE DEVELOPMENT GOAL 8 – DECENT WORK & ECONOMIC GROWTH

The green building industry has continued to expand its contributions to sustainable development and economic growth, especially within the framework of Sustainable Development Goal (SDG) 8, which targets full and productive employment and decent work for all. Recent data highlights the industry's ongoing impact and potential for future growth.

Recent reports indicate that the green building market in the United States has surpassed $83 billion in 2021 and is set to grow significantly in the coming years. The global market for green building materials alone is projected to reach $425.4 billion by 2027, demonstrating a robust growth trajectory driven by increased awareness and demand for sustainable construction practices. This market growth is directly linked to job creation, with green buildings expected to generate 1.7 to 2.5 million additional jobs globally by 2030 .

Green buildings reduce environmental impact and bring significant economic benefits. For instance, companies with LEED-certified buildings have reported up to a 10% reduction in operating costs. Moreover, green buildings are known for their significant reduction in $CO_2$ emissions. There is also evidence suggesting that green buildings can

boost worker productivity by up to 16%, offering an enhanced working environment that can lead to better output and employee satisfaction.

The focus on green buildings aligns with SDG 8's emphasis on creating quality jobs, promoting economic growth, and ensuring environmental sustainability. The green building sector not only offers jobs but also supports a sustainable economy by integrating principles that reduce environmental footprints, improve energy efficiency, and promote renewable energy use.

This sector continues to be a critical part of achieving broader economic and environmental goals, suggesting a promising future for employment in sustainable industries that align with global development goals.


Culled - https://www.decentjobsforyouth.org/theme/green-jobs-for-youth#WHY

Typical, the professionals in green building include architects, climate change analysts, construction managers, energy auditors and modelers, environmental science & protection technicians, fuel cell engineers, industrial ecologists, plumbers, solar energy installation managers, sustainability specialists, civil engineers, electrical engineers, mechanical engineers, project managers, etc.

| JOB TITLE | DESCRIPTION | MEDIAN SALARY | GROWTH PROJECTION (between 2018 and 2028) | LIKELY HIGHEST LEVEL OF EDUCATION REQUIRED |
|---|---|---|---|---|
|  Architects, Except Landscape and Naval | Plan and design structures, such as private residences, office buildings, theaters, factories, and other structural property. | $88,857.60 | 8.4% | Bachelor's Degree |
|  Climate Change Analysts | Research and analyze policy developments related to climate change. Make climate-related recommendations for actions such as legislation, awareness campaigns, or fundraising approaches. | $77,584.00 | 8.2% | Master's Degree |
|  Construction Manager | Construction managers plan, coordinate, budget, and supervise construction projects from start to finish. | $103,105.60 | 9.8% | Bachelor's Degree |
|  Energy Auditors | Conduct energy audits of buildings, building systems, or process systems. May also conduct investment grade audits of buildings or systems. | $76,960.00 | 6.3% | Bachelor's Degree |
|  Environmental Science and Protection Technicians, Including Health | Perform laboratory and field tests to monitor the environment and investigate sources of pollution, including those that affect health, under the direction of an environmental scientist, engineer, or other specialist. | $50,356.80 | 9.2% | Bachelor's Degree |

| JOB TITLE | DESCRIPTION | MEDIAN SALARY | GROWTH PROJECTION (between 2018 and 2028) | LIKELY HIGHEST LEVEL OF EDUCATION REQUIRED |
|---|---|---|---|---|
| Fuel Cell Engineers | Design, evaluate, modify, or construct fuel cell components or systems for transportation, stationary, or portable applications. | $92,809.60 | 4.1% | Bachelor's Degree |
| Industrial Ecologists | Apply principles and processes of natural ecosystems to develop models for efficient industrial systems. | $77,584.00 | 8.2% | Master's Degree |
| Plumbers | Assemble, install, or repair pipes, fittings, or fixtures of heating, water, or drainage systems, according to specifications or plumbing codes. | $58,156.80 | 13.6% | Post-Secondary Certificate–awarded for training completed after high school (for example, agriculture or natural resources, computer services, personal or culinary services, engineering technologies, health care, construction trades, mechanic and repair technologies, precision production) |
| Solar Energy Installation Managers | Direct work crews installing residential or commercial solar photovoltaic or thermal systems. | $70,532.80 | 10.4% | Post-Secondary Certificate–awarded for training completed after high school (for example, agriculture or natural resources, computer services, personal or culinary services, engineering technologies, health care, construction trades, mechanic and repair technologies, precision production) |
| Sustainability Specialists | Address organizational sustainability issues, such as waste stream management, green building practices, and green procurement plans. | $76,960.00 | 6.3% | Bachelor's Degree |

Culled- https://www.usgbc.org/articles/10-green-jobs-high-growth-potential

Green buildings continue to offer significant economic and environmental benefits, reflecting a growing trend towards sustainability in the construction industry. Recent statistics highlight the various financial advantages of green building practices:

Cost Savings: Green buildings typically lead to lower operating costs due to enhanced energy and water efficiency. The average operating cost savings for new green buildings is about 10.5% in the first year and can extend to an average reduction of 16.9% over five years. These savings are primarily due to reduced energy consumption, which can be 30-40% lower compared to traditional buildings.

Increased Property Value: Properties that adhere to green building standards often see an increase in asset value. Recent data suggests that green buildings can command a premium of over 9% in asset value compared to non-green counterparts. This increase is due to their sustainability features, which attract eco-conscious buyers and tenants.

Health and Productivity Benefits: Improved interior environmental quality in green buildings, including better ventilation, natural lighting, and the use of non-toxic materials, not only enhances occupant health but also boosts productivity. Studies have shown that cognitive function in such environments can be significantly higher, with productivity gains attributed to better air quality and natural light.

Job Creation and Economic Growth: The shift towards green construction is also stimulating the job market. With the global green building materials market expected to continue growing robustly, reaching $425.4 billion by 2027, the sector is poised for more job creation and economic opportunities. This growth underscores the sector's resilience and its critical role in sustainable economic development.

Environmental Impact: Beyond economic benefits, green buildings play a crucial role in reducing the carbon footprint and enhancing the sustainability of urban environments. They significantly lower greenhouse gas emissions, reduce water consumption, and contribute to overall energy savings, aligning with broader climate change mitigation goals.

The continued expansion of green building practices reflects strong market recognition of their financial, health, and environmental benefits. These practices support a sustainable future while also providing economic opportunities.

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