SELINUS UNIVERSITY
OF SCIENCES AND LITERATURE

ENVIRONMENTAL SUSTAINABILITY OF THE INDUSTRIES EMERGING GLOBAL TECHNOLOGIES AND FUTURISTIC POLICIES AND PRACTICES

By Santosh M S

Supervised by
Dr. Salvatore Fava PhD

A DISSERTATION

Presented to the Department of
Environmental Engineering
program at Selinus University

Faculty of Engineering & Technology
in fulfillment of the requirements
for the degree of Doctor of Philosophy
in Environmental Engineering

2022

Introduction

Accomplishing sustainable industrial development implies that business and industry will need to change creation constructions and its item blend. Industrial policy should contribute to supporting such an adjustment process. This objective requires an integrated approach to sustainable development encourages increased interrelationship among climate and industrial policies and advances the job of business and industry for the accomplishment of sustainable development.

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (https://www.sustain.ucla.edu/what-is-sustainability/). Sustainable development will obligate account the objectives of environmental protection, economic development and social development. It emphasized the potential of environmentally sound policies to increase industrial competitiveness and create employment opportunities. (Brussels 1999)

Sustainability is an important study; because it improves the quality of our lives, protects our ecosystem and preserves natural resources for future generations. In the corporate world, sustainability is associated with an organization's holistic approach, taking into account everything, from manufacturing to logistics to customer service. Going green and sustainable is not only beneficial for the company; it also maximizes the benefits from an environmental focus in the long-term. (https://bluglacier.com/why-is-sustainability-important/). In the view sustainability development the many aspects are there to be focused, the main aspects which can help us in achieving sustainability were discussed in this report, they are count ably, zero liquid discharge, use of renewable resources and Air pollution control measures.

Need for the study: The aim of sustainable development is to balance our economic, environmental and social needs, allowing prosperity for now and future generations. Sustainable development consists of a long-term, integrated approach to developing and achieving a healthy community by jointly addressing economic, environmental, and social issues, whilst avoiding the over consumption of key natural resources. Sustainable development encourages us to conserve and enhance our resource base, by gradually

changing the ways in which we develop and use technologies. Countries must be allowed to meet their basic needs of employment, food, energy, water and sanitation. If this is to be done in a sustainable manner, then there is a definite need for a sustainable level of population. Economic growth should be supported and developing nations should be allowed a growth of equal quality to the developed nations. There are four objectives of sustainable development: They are

- Social progress and equality
- Environmental protection
- Conservation of natural resources
- Stable economic growth

Everybody has the right to a healthy, clean and safe environment. Everybody has the right to a healthy, clean and safe environment. This can be achieved by reducing pollution, poverty, poor housing and unemployment. No one, in this age, or in the future should be treated unfairly. Global environmental threats, such as climate change and poor air quality must be reduced to protect human and environmental health. The use of non-renewable resources such as fossil fuels should not be stopped overnight, but they must be used efficiently and the development of alternatives should be encouraged to help phase them out. (https://www.yourarticlelibrary.com/environment/what-is-the-importance-of-sustainable-development/9910)

The current research on Sustainability development: Decarbonisation will rise across industry, transport and buildings segments, supported by innovative technologies: The recently published International Energy Agency (IEA) report, Net Zero by 2050, estimated the total CO2 emissions in 2020 to be 33.9 Gt, with the power segment accounting for 13.5 Gt, industry at 8.5 Gt, transport at 7.2 Gt and buildings at 2.9 Gt. To achieve net-zero emissions by 2050, the report based its scenarios on the key pillars of decarbonisation: energy efficiency, behavioural change, electrification, renewables, hydrogen and hydrogen-based fuels, bio-energy, and carbon capture, utilisation and storage (CCUS). In the industry segment, CCUS and hydrogen will account for half of the emission reductions by 2050; however, this will rely on the successful progression of

innovative technologies, which are still in the early stages of development. In the aviation sector of the transport segment, the decarbonisation efforts will rely on hydrogen-based fuels and biofuels. Decarbonisation for the buildings segment relies on two key milestones: all new builds will be zero-carbon ready by 2030, and all existing buildings will be retrofitted to meet standards of zero-carbon-ready building codes. Customer awareness and activism are pushing the environment, social and governance (ESG) agenda. Our recent research analysing key drivers for sustainability in the European manufacturing and built environment sectors highlighted that the most important influencers are not investors or leadership but customers and employees within organisations. The increasing environmental awareness and influence of millennials—as an important customer group with influential roles in organisations—are shaping this transformative change. Millennials and the investment community have driven ESG to be the most strategic priority for organisations. Digital sustainability is shaping the resilience of water utilities and reducing carbon emissions in sectors such as water and resource recycling: Digital sustainability is driving much-needed operational efficiency improvements in key sectors such as water services, waste management, and recycling. Digital Twins is emerging as one of the fastest-growing market opportunities in the water sector as we witness an increasing number of use cases across a range of assets from networks to treatment plants. These projects highlight the value of digital twins in enhancing the resilience of water utilities while offering an attractive return on investment. By driving operational efficiency, they are also supporting carbon emission reduction. Digital transformation in waste recycling is also witnessing rapid growth, driven by the deployment of monitoring and metering solutions as well as advanced sensors coupled with artificial intelligence (AI) for better sorting and waste segregation. Cloud-based data platforms for better decision support facilitate a truly circular approach. Design for environment and supply chain sustainability with an emphasis on the Scope 3 decarbonisation strategy: The decarbonisation strategy for many organisations is rapidly evolving. In recent years, some have also achieved carbon-neutral status for Scope 1 and 2 emissions. However, in most cases, more than three-quarters of carbon emissions are in Scope 3, covering the supply chain upstream and downstream and involving big

challenges in complexity and number of stakeholders. This presents an opportunity focussed on the environment, with life cycle analysis and greater scrutiny of material selection based on sustainability credentials. The expansive nature and coverage of scope 3 will drive the rapid growth of supply chain sustainability software solutions and services to provide an integrated, end-to-end solution covering upstream sourcing to downstream recycling. Sustainability as a service is emerging as a strong business model to drive behavioural change and provide purpose-driven outcomes for customers: Behavioural change is one of the key pillars of decarbonisation. In many customer-focussed sectors, digital platform-based solutions in the form of Sustainability as a Service business models provide a much better understanding of customers. They drive cross-sector collaboration and partnerships to deliver tangible, purpose-driven outcomes of products and services for customers. This will be particularly significant in the business-to-business and business-to-government segments, with the customers looking to suppliers for partnerships and support for their decarbonisation efforts. (https://www.frost.com/frost-perspectives/top-5-trends-for-environment-sustainability-in-2021/). "Using collaborative hackathons to coproduce knowledge on local climate adaptation governance": This paper talks about, while coproduction of knowledge is growing in popularity in social sciences, and especially climate change research, still its need a better understand how to coproduce climate knowledge. In this paper, it explores how collaborative climate hackathons coproduce local adaptation knowledge, and what this method reveals about local climate governance. The collaborative group work revolved around the challenges and solutions of local adaptation planning and uncovered how a diversity of key actors understands the local adaptation work in Norway. These interventions revealed that there are significant disagreements and divergent understanding of relevant laws, regulations and responsibility between practitioners working within the same governance system. (Kvamsas et al., 2020)

The following Venn diagram shows that the aspects that have been included in sustainable development

Figure 1: Schematic Venn diagram of Sustainability development

(http://emeraldbe.com/sustainable-development-important/)

As we all aware, the growing population leads to increase in the demand for Natural resources, the present developmental activities are not only consuming the natural resources, they are actually polluting the present natural resources, if this continues the future generations may experience the scarcity of resources even the renewable resources are abundant, pollution may cause renewable resource a unusable. In concern of making industries to replace the non-renewable energy sources with renewable energy sources, it is necessary to focus on the pollutions of existing industries, hence to know the current pollution load to provide mitigation measures, to create awareness about the renewable energy sources to make use of it and to achieve ZLD within the industries, these kind of studies are useful. Other countries measures w.r.t Industrial sustainability: The Lima Declaration, adopted by UNIDO's Member States in December 2013, set the foundation for a new vision of inclusive and sustainable industrial development (ISID) and highlighted the role of industrialization as a driver for development. Inclusive and sustainable industrial development (ISID) is the primary source of income generation, allows for rapid and sustained increases in living standards for all people, and provides the technological solutions to environmentally sound industrialization. Technological progress is the foundation of efforts to achieve environmental objectives, such as

increased resource and energy-efficiency. Without technology and innovation, industrialization will not happen, and without industrialization, development will not happen.

"Inclusive" in this context means that industrial development must include all countries and all peoples, as well as the private sector, civil society organizations, multinational development institutions, and all parts of the UN system, and offer equal opportunities and an equitable distribution of the benefits of industrialization to all stakeholders. The term "sustainable" addresses the need to decouple the prosperity generated from industrial activities from excessive natural resource use and negative environmental impacts. ISID therefore implies that no one is left behind and all parts of society benefit from industrial progress, which also provides the means for tackling critical social and humanitarian needs.

Over the past few years, the international community has made a quantum leap in advancing new approaches to accelerate progress and pave the way for a more ambitious, inclusive and universal development framework beyond 2015. While industrialization was not factored into the Millennium Development Goals framework, inclusive and sustainable industrialization now features strongly in the 2030 Agenda for Sustainable Development.

ISID enhances and reinforces economic growth and diversification in a socially inclusive and environmentally sound manner, guided by four overarching principles:

1. No one is left behind in benefiting from industrial growth, and prosperity is shared among all parts of society in all countries as industry creates the wealth needed to address critical social and humanitarian needs.
2. Every country is able to achieve a higher level of industrialization in their economies, and benefits from the globalization of markets for industrial goods and services.
3. Broader economic and social progress is supported within an environmentally sustainable framework.

4. The unique knowledge and resources of all relevant development actors are combined to maximize the development impact of ISID. (https://www.unido.org/inclusive-and-sustainable-industrial-development)

Objectives

The objectives of the study are:

- To understand the concept of environmental sustainability to know the various technologies associated with Industries to support sustainability.
- To analyze the uses of renewable energy sources in industries.
- To understand the national and international polices associated with the concept of environmental sustainability.
- To understand the concept of green building and its significance.
- To assess the implementation of the environmental and energy management policies in the industries.
- To understand the global current scenario of industries with respect to sustainability.
- To assess the concept of concept to running economy by adopting 7Rs.
- To understand the segregation of wastes and its management to support sustainability.
- To understand the statistical data of various waste management activities.
- To understand the result of failure of implementation of the concept of sustainability in industries.
- To understand the concept of waste water treatment and air pollution control measures in industries.
- To know the importance of focusing on cost effective and highly ecofriendly measures.
- To assess the emerging opportunities in environmental industrial sustainability.
- To understand the benefits of continuous monitoring and reviewing of the sustainability reports.

Materials & Methods

The study was carried out by reviewing various articles published by different authors from various countries. The study searched for various aspects of Environmental Sustainability. During the study, various professional experts from Environmental Health and Safety (EHS) departments of different industries suggestions were taken and adopted in the thesis. The study also focused on various MNC company websites for knowing the technologies and policies adopted in their organization to support sustainability. The India's government authority's websites are also checked for mentioning the rules and regulation in the thesis. Various statistical data's are presented in the graphical representation to show the current global scenarios and recent trends. The study focused on the emerging technologies adopted in the industry to self-sustain in terms of sustainability. The contents are categories into various sections as follows:

Environmental Sustainability of the Industries

- ***Waste Management***
- ***Use of Renewable Resources***
- ***Zero Liquid Discharge***
- ***Rain Water Harvesting***
- ***Green Belt Development***
- ***Air Pollution Control Measures***
- ***Environmental Monitoring***
- ***Utilization of Eco friendly Technologies***
- ***Setting up of Environmental Sustainability Targets***
- ***Adoption of Environmental Policies***

Result & Discussion

Waste Management

Solid Waste Management in Industries

Solid waste is any unwanted or discarded material that is not a liquid or a gas. It can include organic waste, paper, metals, glass, yard waste and wood. The varieties of products manufacture and usage by people, resulting give rise to produce thousands of tons of solid wastes. The volume of waste is projected to increase from 64-72 million tonnes at present to 125 Million tons by 2031 (www.cpcb.nic.in).

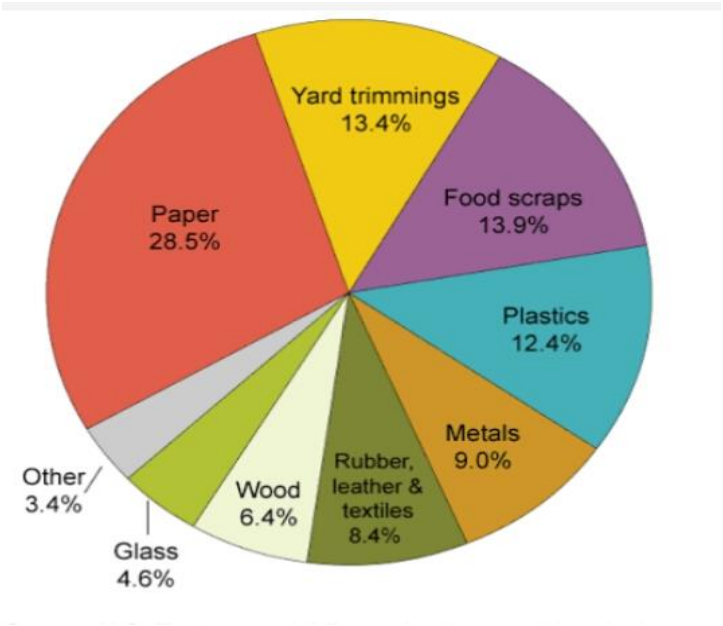

Fig 1: Classification of Solid Waste in Industries (Source: U. S. Environmental Protection Agency, 2011)

Segregation and Recycling of Solid Waste

Segregation is one of the industrial waste disposal methods that is vital to our environment for two reasons: it's safer for the atmosphere, and it's also a method that will ensure that waste is processed and disposed of correctly. Proper waste separation means that recyclable materials are reused in the manufacturing of new goods.

Much of the waste that is generated by your company's production, shipping, and packaging needs is not reusable or compostable, but it is recyclable. The first step in your industrial waste management program is to identify which items can be recycled, and set up recycling bins or dumpsters into which they can be sorted. Most recycling centers can handle glass, paper, and plastic recycling. Many can also handle scrap metal recycling,

cardboard recycling, food waste recycling, and electronics recycling. (Abd Rahman *et al.*, 2018).

- **Organic Waste:** Organic waste placed in a plastic container, waste is disposed of in the green bin, and the excess waste is disposed of in the residual waste bin.
- **Plastics:** Hard plastic may usually be recycled, they can be melted and moulded into new products. Some super market offer to recycle soft plastic such as grocery bags, cling bubble rap.
- **Packaging Waste:** Purchasing in bulk will help you save money on packing and shipping. If you can avoid it, aim to buy goods with less packaging. To stop having to use single-use plastic bags, remember to bring reusable bags with you.
- **Aluminum and Steel:** When recycling steel cans, it's best to put the lid inside the can and then squash the top of the can before placing it in your recycling bin.
- **Electronic Waste:** Many pieces of e-waste will and should be recycled, allowing the energy to be reused. E-waste also contains a number of toxic elements, such as mercury, which if not properly disposed of may be released into the atmosphere. E-waste cannot be recycled in a regular garbage can, but it can be recycled or properly disposed of using other facilities.
- **Bathroom, Toilet and Laundry:** Chemicals will accumulate quickly in the shower, toilet and laundry. This technically counts as hazardous waste, unless it is rinsed and properly cleaned, will usually not be of value to recycling plants. You can counteract this by limiting the chemicals and waste you flush into the toilet and sink.
- **Kitchen and Food:** When routting food is thrown away into the landfill without the proper care of sorting, it produces methane, a gas that is particularly harmful to the atmosphere. By taking the time to plan your trips to the grocery store, you can prevent unnecessary waste of food.

Composting:

The composting process turns organic waste into fertilizer that can be used nourish plants. Most food waste can be composted, and even unsafe organic items can be turned into safe composting. We can compost food waste, leaves, newspaper, very small pieces of cardboard, sawdust. Compost is then added to soil to provide nutrients and encourage growth. Composting is one of the most effective ways to reuse and recycle waste (Sharma Mona *et Al.*, 2017).

Landfill:

Landfills are one of the most common ways to disposed of waste. The only waste that should be sent to landfills is that which is non-hazardous, non-recyclable and non-compostable. When waste is send to landfill, it is confined to a small area, compacted when necessary, and then buried in the earth. As the waste decomposed releases gases that can be converted natural gases used for power and fuel. Landfills are cost efficient and are designed to minimize the harm done to the environment. (Jaspal Singh *et al.*, 2017)

As per the **Solid Waste Management Rules, 2016** (India) the rules are now applicable beyond municipal areas and extend to urban agglomerations, census towns, notified industrial townships etc. The source segregation of waste has been mandated to channelize the waste to wealth by recovery, reuse and recycle.

Responsibilities of Generators have been introduced to segregate waste into three streams, Wet (Biodegradable), Dry (Plastic, paper, metal, wood, etc.) and domestic hazardous wastes (napkins, empty containers of cleaning agents, mosquito repellents, etc.) and handover segregated wastes to authorized rag-pickers or waste collectors or local bodies. All such manufacturers, brand owners or marketing companies should educate the masses for wrapping and disposal of products. All industrial units using fuel and located within 100km from a solid waste based Refuse Derived Fuel (RDF) plant shall make arrangements within six months from the date of notification of these rules to replace at least 5% of their fuel requirement by RDF so produced.

Problems of unscientific solid waste disposal leads to only about 75-80% of the solid waste gets collected and out of this only 22-28% is processed and treated and remaining is disposed of indiscriminately at dump yards. It is projected that by the year 2031 the solid waste generation shall increase to 165 million tons of waste by 2031, the requirement of setting up of land fill for 20years of 10 meters height will require 66,000 hectares of land. (Patel and Ahluwalia *et al.*,2018).

- Improperly disposing of waste prevents resource from being reused. This is particularly true of plastics, metals and paper. This loss of resources means a heavier reliance on virgin materials, which often require more energy to make new products than required by reusing existing resources.
- Improper disposed of waste releases greenhouse gases into the atmosphere.
- Some waste contains chemicals that can be released into the environment if not disposed of properly. These includes electronics, plastics, batteries, certain types of pressure treated wood and paint.

Proper solid waste management includes scientific disposal of solid waste through segregation, collection and treatment and disposal in an environmentally sound manner minimizes the adverse impact on the environment.

As per information available for 2013-14, complied by Central Pollution Control Board, municipal authorities have so far only set up 553 compost & vermi-compost plants, 56 bio-methanation plants, 22 RDF plants and 13 waste to Energy plants in the country (www.vikaspedia.in).

The nature and components of waste generated by households and industries, the waste reduction, reuse, recycling and composting processes would be more suitable in managing the challenge. These management options should be integrated in a sustainable framework.

Hazardous Waste Management in Industries

Hazardous waste is defined broadly under the rules to include any waste that, by virtue of its characteristics, "causes danger or is likely to cause danger to health or environment, whether alone or when in contact with other wastes or substances". For example: Mercury bearing sludge, Date-expired, discarded and off-specification drugs/medicines. (https://www.cpcb.nic.in)

Characteristic of Hazardous Waste

According to the EPA, if a substance shows one or many of the following characteristics upon self-reaction or reaction with other compounds, it may be classified as a hazardous substance. These characteristic features are defined as follows:

1. **Ignitability**: Any waste product that can create fire under certain conditions, has a flash point of less than 60•C and shows spontaneous combustible characteristics can be called an ignitable product.
2. **Corrosively:** All the acids or bases and /or any waste product that are capable of causing corrosion in metal containers.
3. **Reactivity:** If any material is unstable under normal conditions, it can be considered a reactive hazardous waste. These products may cause explosions, under violent reactions, generate toxic fumes, gases or vapors or explosive mixtures when heated, compressed or mixed with water.
4. **Toxicity:** A waste product is referred to as toxic when its proven to be harmful or fatal upon ingestion or adsorbed. (Saurabh Shukla et al.,2020)

Table 1: List of hazardous waste generating processes

Industry	**Hazardous Waste**
Petrochemical processes and pyrolytic operations	Furnace/reactor residue and debris, Tarry residues, Oily sludge emulsion, Residues from alkali wash fuels, Still bottoms from distillation process, Spent catalyst and molecular sieves, Slope oil from wastewater.
Drilling operation for oil and gas Production	Drill cuttings containing oil, Sludge containing oil, Drilling mud and other drilling wastes.
Aluminum Smelter	Sludge's from off-gas treatment, Fuel gas and other particulates, waste from the treatment of salt slags and black drosses.
Pulp and paper	Spent chemicals, corrosive wastes arising from use of strong acid and bases
Sugar	Sugar processing wastewater with a high content of organic material and high biological oxygen demand.
Thermal power plant	Oil and grease copper, iron, cooling tower low down (chlorine, zinc, chromium, phosphate, corrosion inhibiting materials, ash pond effluent, suspended solids.
Zinc Smelter	Sludge and filter press cake arising out of production of zinc sulphate and other zinc compounds ,zinc fines /dust /ash/skimming, fuel gas and other particulates
Fertilizer	Spent catalyst, spent carbon, sludge /residue containing arsenic, chromium sludge from water cooling tower
Dyes and Dye Intermediates	Process waste sludge /residues containing acid or other toxic metal or organic complexes, dust from air filtration system

Source: (Anita S. Ahuja and Sachin D. Abda, 2015)

Table 2: Method of Handling Hazardous Waste

Waste Category	Hazardous waste	Method of handling
5.1	Used Oil	Collected in leak proof containers and disposed only to Pollution Control Board registered authority
5.2	Oil soaked cotton waste	Stored in a secured manner and hand over to Pollution Control Board authorized incinerator
28.1	Process residues &Waste	Stored in a secured manner and hand over to Pollution Control Board authorized incinerator /Co processing in cement kiln
20.3	Distillation Residue	Stored in a secured manner and hand over to Pollution Control Board authorized incinerator
28.2	Spent solvent	Stored in a secured manner and hand over to Pollution Control Board authorized recycler
33.1	Discarded containers	Stored in a secured manner and hand over to Pollution Control Board authorized recycler after wash/decontamination only
35.3	Sludge from ETP & MEE salts	Stored in a secured manner and hand over to Pollution Control Board authorized TSDF

Source: (Environmental clearance from SEAC, karnataka. EIA/EMP Report)

Issues of concern:

After knowing the various types of hazardous waste we need to know the effect of such hazardous waste on human and environment. As all the waste is needed to be disposed of the 8same goes with the hazardous waste. But here if this waste is not disposed properly it can cause harm to the environment as land, water and air pollution causing effects on agricultural water supplies ultimately those chemicals leads to serious effects that are shown in the below table.

Table 3: Hazardous waste and their effect on health

Substance	**Potential Health Effects**
Arsenic	Carcinogenic to humans (skin, lung, bladder, liver) - Stomach and intestinal irritation, nausea, vomiting
Benzene	Carcinogenic to humans, harmful to bone marrow, decreased red blood cells, anemia ,unconsciousness
Cadmium	Likely to be carcinogenic to humans – kidney ,bone, and lung damage
Chloroform	Likely to be carcinogenic to humans – liver and kidney
Lead	Damage to the brain and nervous system, miscarriage, premature births, increased blood pressure
Mercury	Brain, kidney and lung damage – serious harm to neural development of fetuses and young children
Trichloroethylene	Carcinogenic to humans, skin rashes, lung irritation, headaches, dizziness, unconsciousness

Source: (M. D. LaGrega et al.,2010)

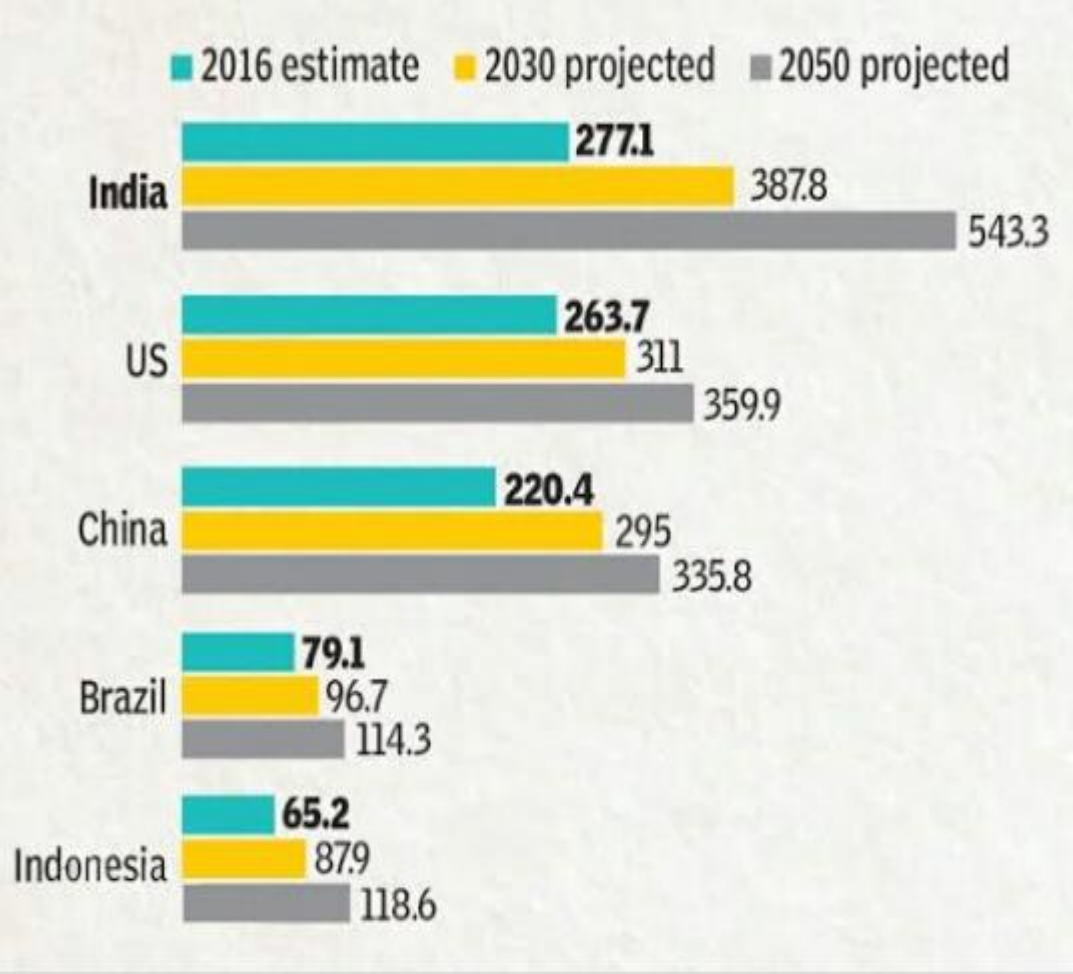

Fig 2: Top- 5 Countries that produces the most Hazardous Waste (In million tons) Source: (timesofindia.indiatimes.com)

As per the Hazardous Wastes (Management and Handling) Rules, 1989, as amended to date, were notified in the country under the provisions of the Environment (protection) Act, 1986, for management and handling, and import of hazardous waste into the country. These rules were amended in 2000 and 2003 to bring the Rules in line with the requirements of the Basel Convention and also to improve the applicability and implementation aspects with regard to imports of hazardous waste. Apart from Ministry of Environment and Forests (MoEF), Central Pollution Control Board (CPCB), State Pollution Control Boards (SPCB)/Pollution Control Committees (pccs) have been delegated certain power for control and regulation of hazardous waste.

Basel Convention

Basel Convention deals with the trans-boundary movement and disposal of hazardous wastes as well as other chemical wastes by regulating and controlling the movement of scheduled hazardous wastes from OECD countries to NON-OECD countries. India is a party to the Basel Convention on trans boundary movement of hazardous wastes. The basic objectives of the Basel CO are for the control and reduction of trans boundary movements of hazardous and other wastes subject to the Convention, prevention and minimization of their generation, environmentally sound management of such wastes and for active promotion of the transfer and use of cleaner technologies.

World Initiatives

After the Bhopal Gas Tragedy in 1984,USA enacted the 'Emergency Planning and Community Right to Know Act, 1986', which may considered as a pioneering legislation regarding 'Community Right to Know'. Industries must prepare emergency response plans with discussion and due representation of the local community. (Shantanu K Dutta, et al.,2006).

Technologies for Hazardous Waste Management

The treatment of hazardous waste can be broadly classified into physical, chemical and biological methods of treatment followed by disposal of waste and residues. (U Sridharan et al.,2006).

Incineration

Incineration is the process of destruction of all high calorific and highly toxic wastes by burning the waste at high temperature. Incineration at 1200•C mineralises (breaks down into basic non-toxic components) all kinds of organic matter in the waste. Incineration serves the dual purpose of reduction of both the toxicity and the volume of the waste, which is an important consideration when the disposal of wastes is finally destined for landfills.

Use of hazardous waste as fuel

There are 250 cement works located in the European Union, which, altogether are using around 3 million tons of hazardous waste as alternate fuels. This is over 10 percent of the fuels used and the figure is rising steadily across the European Union with countries such as Germany leading the way.

There are a large number of hazardous wastes generating units located in the Country. 11,138 units have been given authorization by SPCBs under Hazardous Waste (Management and Handling) Rules, 2003, mostly for temporary storage of hazardous waste within the plant premises. In India, about 4.43 million tons of hazardous waste are

generated annually, out of which 71.833 tons are incinerable (as per the reports of SPCBs submitted to the Hon'ble Supreme Court).

Hazardous wastes landfill

'Hazardous wastes landfill' refers to a waste disposal unit, which is designed and constructed with the objective of minimum impact to the environment. The hazardous waste landfill site is designed scientifically to have an impervious stratum at bottom to stop leachates percolation, and thus to avoid soil and water pollution in the vicinity of the landfill site. Reduction and minimization of hazardous waste is absolute requirement in today's world. (D. A. Rubinos and G. Spagnoli, 2018)

Advantages of maintaining hazardous waste

- **Protect Habitats:** Incorrect disposal of hazardous waste, such as solvents and heavy metals, can cause toxic substances to seep into the soil and contaminate the water supplies and habitats of many nearby fauna. Once these substances have been absorbed into the earth, they are very difficult to clean up and can have a substantial detrimental effect on the local ecosystem. Choosing to recycle your waste reduces this risk and help keeps the balance of the local wildlife intact.
- **Reduces Consumption of Raw Materials:** Recycling means that fewer raw materials will be needed for production, when it comes to hazardous waste that is especially beneficial as it means less hazardous produce will be created for use in the next generation of products, maintaining a steady level, or lowering the amount of hazardous waste, in the environment.
- **Burn Fewer Fossil Fuels:** Fossil fuels are a limited resource and preserving them is of utmost importance.
- **Reduce Emissions :** By reducing the amount of fossil fuels burned in the creation of hazardous products, the amount of harmful emissions, such as carbon dioxide, that are released into the atmosphere are reduced.

It is difficult to develop alternative technology for total elimination of hazardous wastes generation. In developing countries, the thrust on economic development is often given priority to production costs than the best available technology and this results in more wastes generation. The cost of treatment and disposal of such wastes becomes a liability on the society. Regional Hazardous waste facility shall be more economical, profitable and will serve the requirement of a region, thus, eliminating the scope of scattered impact of many such facilities of smaller scale.

Use of Renewable Resources

An ever growing population means an ever growing requirement for energy. Nowadays, enormity of energy cannot be denied. It is essential in every walk of life. Energy sources can be broadly classified as renewable and non-renewable. Knowing the dreadful fact that non-renewable sources will eventually deplete, the importance of renewable sources cannot be underestimated. The most important aspect while utilizing them is their impact on the environment. This paper briefly presents the importance of renewable sources of energy owing to the backdrop of fossil fuel dilemma. Major emphasis is placed on the use of alternative energy technologies. Some applications of renewable sources and future of energy is also discussed.

Renewable energy sources: Renewable energy is the energy which is derived from a limitless source.

Proper utilization of energy resources is a hot debate going these days. It is very essential to choose which source of energy must be used and why. Majority of factors such as cleanliness, cost, stability, efficiency and environmental effects must be taken into account. It is a bitter fact that many industries around the world are still dependent on fossil fuels for electricity generation. No doubt, these fuels are very effective as far as power production quality is concerned, but in the long run they are not advantageous. Fossil fuels will deplete one day and the industries must turn to renewable sources as soon as possible. Moreover, these fossil fuels pose a huge threat to environmental balance and are a cause of many ecological hazards.

The most significant feature of renewable energy is its plentiful supply. It is infinite. Renewable energy sources are hygienic sources of energy that have a much lesser negative environmental impact than conventional fossil energy technologies. Most renewable energy investments are spent on materials and personnel to build and maintain the facilities, rather than on costly energy imports. With technological advancements in mass communication, people have now become aware of the demerits of burning fossil fuels. Renewable energy is the need of the hour. Its clean and sustainable nature has compelled the human beings to think seriously about it. Scientists and Engineers, around the world, are continuously working and researching in this domain. They are finding new ways to use these sources of energy effectively. Global warming is a huge hazard which is being caused by burning of coal, oil and natural gas. It is very harmful for the planet and the living beings on it. Moreover, fossil fuels are a cause of many unfortunate mishaps in the past as described before. To put an end to this apocalypse; we must resort to renewable sources. This is because they are cleaner and do not produce poisonous harmful gases. Moreover, fossil fuels are finite. They will certainly end one day. Therefore, before the crucial stage comes up, experts of energy sectors must maintain a

positive attitude in this regard and should try their level best to replace fossils fuels with renewable energy sources as the main sources of generating electricity. (Shahzad 2017)

Renewable energy availability changes how we operate modern mines, fuel cars, and supply near-by communities with heating and cooling. Renewable energy is an affordable choice for miners, who use it to crush, dig, and process minerals. Renewables (or green energy) are generated from sources that replenish over time.

The most common uses of renewable energy in the industry involve:

- Wind energy
- Solar energy
- Biodiesel energy
- Geothermal energy
- Hydropower energy
- Hydrogen and fuel cell energy
- Geothermal power energy
- Tidal energy (4 Ways the Mining Industry Uses Renewable Energy | Anglo American)

Sources of renewable energy:

The sources could sustain for a longer period of time and can easily be renewed often. Sustainable sources are biomass, nuclear power, geothermal, wind energy, solar power, tidal power, and wave power. The sources of renewable energy are known to be less polluting and therefore the whole world is looking forward to new carbon emission norms, where carbon will play a major role in developing new factories and industries. They will be rated according to the carbon emission and the products that they are producing will be rated accordingly.

Integration of solar energy into industrial systems

A typical industrial energy system is composed of 4main parts; power supply, production plant, energy recovery and cooling systems. Figure no. 1 shows a block diagram of a typical industrial energy system.

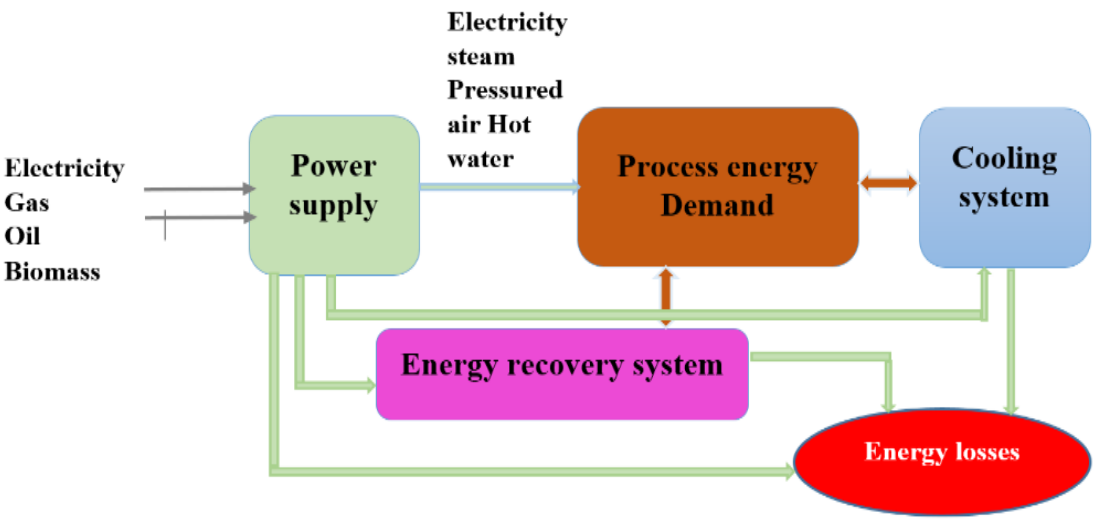

Fig 3: Block diagram of a typical industrial energy system. (Mekhilefa *et al.*, 2011).

The power supply provides the energy needed for the system to operate mainly from electrical energy, heat, gas, steam or coal. Production plant is the part of the system that executes proceedings of production. Energy is utilized in this part for running subsystems, pressure/vacuum/temperature solenoids, valves and switches. (Mekhilefa *et al.*, 2011).

Types of Renewable energy

1. **Solar Energy:** The radiant light and heat energy from the sun is harnessed with the use of solar collectors. These solar collectors are of various types such as photo-voltaic, concentrator photo-voltaic, solar heating, (CSP) concentrated solar power, artificial photosynthesis, and solar architecture. This collected solar energy is then used to provide light, heat, and different other forms of electricity. The below figure shows that the solar panel setup in an empty space **(**Proctor and Morse 1977).

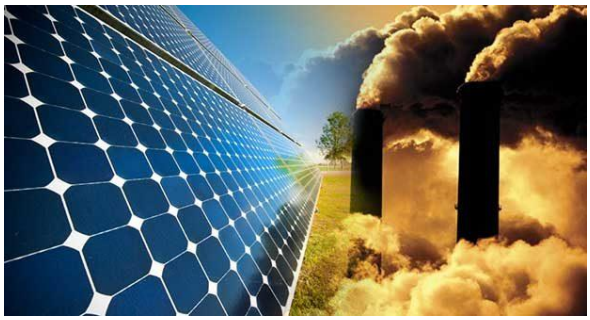

Fig 4 : Solar panels setup (solar energy utilization in industries - Bing images)

Solar energy systems can either be applied as the power supply sector or directly to a process. Table 4 has tabulated the solar energy applications and the technologies adopted in industrial processes.

Table 4: Solar energy applications, system technologies and type of systems commonly used in industry (Soteris 2004.)

Solar energy application	Solar system technology	Type of system
SWH	Thermo syphon systems	Passive
	Integrated collector storage	Passive
	Direct circulation	Active
	Indirect water heating systems	Active
	Air systems	Active
Space heating and cooling	Space heating and service hot water	Active
	Air systems	Active
	Water systems	Active
	Heat pump systems	Active
	Absorption systems	Active
	Adsorption (desiccant) cooling	Active
	Mechanical systems	Active
Solar refrigeration	Adsorption units	Active
	Absorption units	Active
Industrial heat demand process	Industrial air and water systems Active	Active
	Steam generation systems	Active

Solar desalination	Solar stills	Passive
	Multistage flash (MSF)	Active
	Multiple effect boiling (MEB)	Active
	Vapor compression (VC)	Active
Solar thermal power systems	Parabolic trough collector systems	Active
	Parabolic tower systems	Active
	Parabolic dish systems	Active
	Solar furnaces	Active
	Solar chemistry systems	Active

It can be stated that solar thermal is the conversion of solar irradiation into heat. Among renewable energy systems, solar thermal is considered as the most economical alternative. Typically, the systems use solar collectors and concentrators to gather solar radiation, store it and use for heating air or water in domestic, commercial or industrial plants. Figure no. 3 presents a schematic diagram of solar irradiation conversion to mechanical energy. (Goyal and Tiwari 1999).

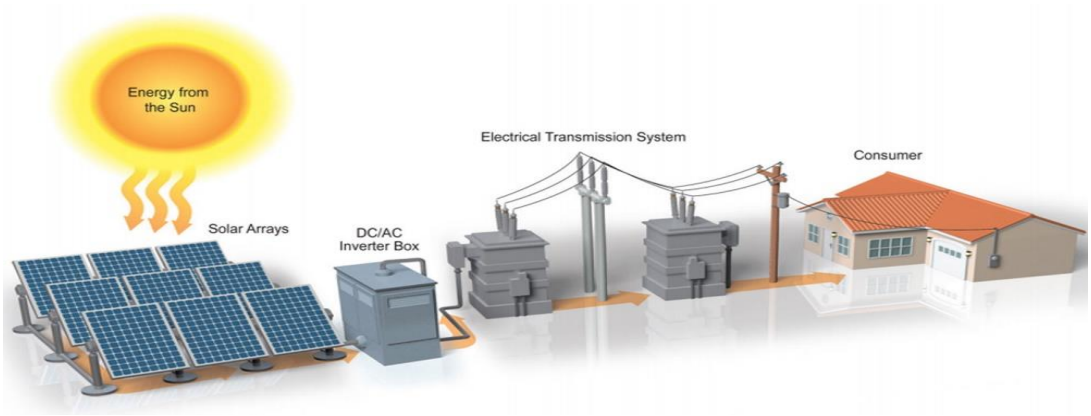

Fig 5: Solar power generation mechanism (process of Solar Energy generation Systems - Bing images)

However, it has to be noted for some applications that solar energy is not available continuously for 24 hr. In such cases, addition supplementary measures should be provided to accumulate solar irradiation during sunny days, store it in an embedded phase transition and release it in a controlled manner in severe conditions. To increase the efficiency of solar thermal systems, solar collectors are applied to heat the air or water as the medium of heat transfer.

However, each collector is dedicated for a specific application. For example, flat-plate collectors are properly designed to be used in low temperature applications, the concentrating and sun-tracking parabolic trough collectors (PTC) are suitable for high temperature applications in which the system can obtain temperature higher than 250 ◦C with high efficiency, two axes tracking collectors are applied in power generation, stationary (non-tracking) and one axis PTCs are mainly used in industrial heat processes.

Among the collectors, movable collectors require higher maintenance cost compared to other collectors. A concentration ration, defined as the aperture area divided by the receiver/absorber area of the collector of each type is presented as well. Cost of the energy generated by solar thermal systems varies from 0.015 to 0.028 C£/kWh depending on initial investment and the type of solar collectors used. Large scale solar thermal systems with large collector fields are more economical. They need less initial investment compared to several small plants; however, the collector cost is higher. (Kalogirou 2003).

2. **Wind Energy:** The energy we get from winds is known as wind energy. For this, windmills have been used for hundreds of years to pump out water from the ground. We use large tall wind turbines that allow winds to generate electricity. The natural airflow on the surface of the earth is used to run the wind turbines. The modern-day wind turbines range from about 600 Kilowatt to 5 Megawatts, for commercial purposes these are rated with an output power of 1.5 to 3 Megawatts. The most preferred locations for these wind turbines to be installed are the areas which and strong and have constant airflows on offshore and sites that are at high altitudes. The power generated from wind energy in 2015 met 4% of global energy consumption.

Fig 6: Windmill Setup (windmills in industries - Bing images)

Innovative uses of wind energy

Our nature is a source of energy in many forms. Wind is one such energy, which is in abundance and is totally environment friendly. It is also one of the most preferred sources of clean energy. Wind energy has been used by man since time immemorial and is still being used in various forms. You must have seen windmills with their propellers rotating in the wind that is used to convert wind energy into electricity. Many ways of tapping wind energy are known to most of us but there are few that we don't know. Here is a list of 5 Innovative uses of wind energy. (5 Innovative uses of wind energy and the countries using them - Green Diary - A comprehensive guide to sustainable hacks, green tips, and eco suggestions)

- **Power generating windmills or wind turbines**

Wind turbines are one such power generating machines that use wind energy as the source of energy to generate power. Many such turbines are being used worldwide on a large scale and even individual smaller turbines are used. The principle is to tap the ever-flowing energy of the wind to rotate the propellers that rotates the turbines to generate electricity. This electricity is then stored in the batteries and/or used to run electric devices. These days wind turbines are being used to provide green power to various industries and residential complexes. Green power is also an economical option for people on a budget.

- **Wind powered vehicles**

Wind powered vehicles are a great option for people who want to go green. In Australia, it was recently proved that we can use wind power to run our vehicles. Recently a car was made to run 3100 miles in Australia with the help of kites harnessing the power of wind. When in motion the cars batteries were charged and then this stored power was used to run the car when there was no wind. Nevertheless, it was proved that a car could be run solely on just wind energy. The total cost of running the car to 3100 mile came out to be $15, it's really green and economical and one of the most Innovative uses of wind energy.

- **Wind powered sea ships**

One of the most ancient uses of wind power as seen in history is the use of wind energy to power the motion of sailing ships in the sea. It is one of the most abundant sources of energy. This green source of energy once used to power small boats and ships to sail is now recently been used to power a cargo ship too. This was done by attaching a huge kite. By doing so this dramatically reduced the consumption of fuel and reduced carbon dioxide emission, thus conserving the nature.

- **Innovative uses of wind energy in sports**

Hundreds of sports have used the power of wind to energize our passion for sports. Adventure lies in speed and many sports use wind energy to enhance the thrill. This helps to provide a thrill and speed up these sports. Everything from simple kite flying to sailing in the river/sea, kite surfing, para-sailing, wind-skiing and many more are being powered by the energy of wind. Hot air balloon sports also use the power of wind energy to move from one place to another. Being a natural source of energy that is 100% green and leaves no harmful residue the power of wind is a great way to energize the sports.

- **Wind powered water pumps**

In many countries and communities, people use the power of wind energy to pump water out of the ground. The process is simple and uses wind turbines. The only difference is that this time the mill does not rotate the turbine. However, you can use it to move the water pump, in turn forcing the water to pump out of the ground. The use of wind energy to pump water is a great way to help a village or community. This is helpful especially in the case where there is a need of continuous supply of water. This helps to provide water for daily needs as well as for irrigation purposes for farming.

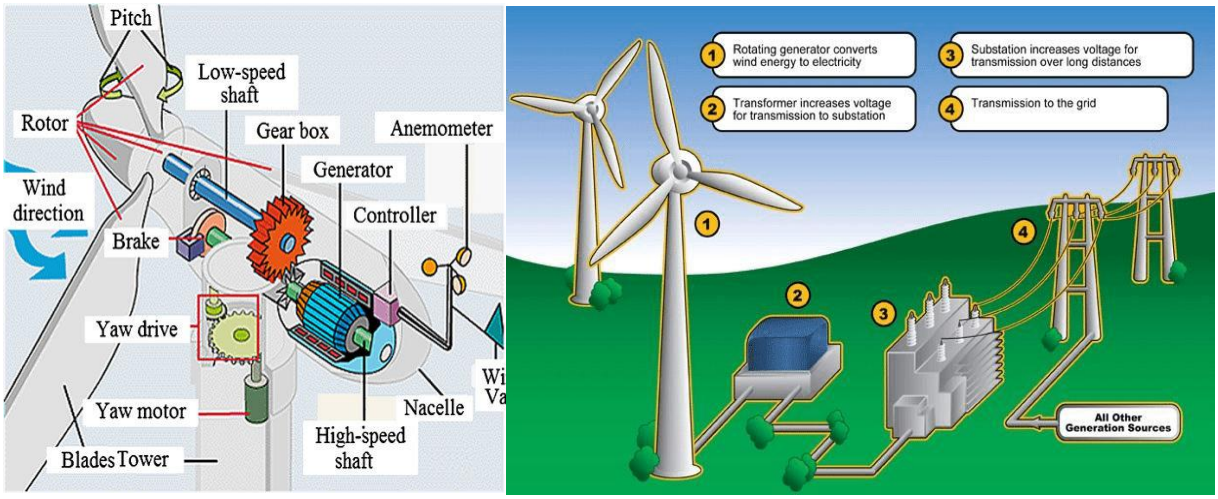

Fig 7: Windmill Mechanism (windmills in industries - Bing images)

The majority of wind turbines consist of three blades mounted to a tower made from tubular steel. There are less common varieties with two blades, or with concrete or steel lattice towers. At 100 feet or more above the ground, the tower allows the turbine to take advantage of faster wind speeds found at higher altitudes. Turbines catch the wind's energy with their propeller-like blades, which act much like an airplane wing. When the wind blows, a pocket of low-pressure air forms on one side of the blade. The low-pressure air pocket then pulls the blade toward it, causing the rotor to turn. This is called lift. The force of the lift is much stronger than the wind's force against the front side of the blade, which is called drag. The combination of lift and drag causes the rotor to spin like a propeller. A series of gears increase the rotation of the rotor from about 18 revolutions a minute to roughly 1,800 revolutions per minute -- a speed that allows the turbine's generator to produce AC electricity.

3. **Hydroelectricity:** According to statistics, hydroelectricity generated around 16.6% of the global energy resources and constituted about 70% of all the renewable electricity. This energy is another alternative source of energy that is generated by the construction of dams and reservoirs on the flowing water, the kinetic energy from the flowing water is used to run the turbines which generate electricity. Tidal power converts the energy of tides and Wave power which captures the energy from the surface of the ocean waves for power generation. These two forms of hydropower also have huge potential in electric power generation

4. **Geothermal Energy:** It is the energy that is generated from the thermal energy which is stored in the earth. The heat energy is captured on sources such as hot springs and

volcanoes and this heat is directly used by industries for heating the water and other purposes.

5. **Bio-energy:** This type of energy is derived from the biomass which is a type of biological material derived from living organisms and plant-derived materials which are called lingo cellulosic biomass. Biomass can be directly used via combustion to produce heat and indirectly it can be used to convert to biofuels. Biomass can be converted to other usable forms of energy such as transportation fuels like ethanol, biodiesel, and methane gas. (Allakhverdiev *et al.,* 2009)

It is increasing clear that biofuels can be a viable source of renewable energy in contrast to the finite nature, geopolitical instability, and deleterious global effects of fossil fuel energy. Collectively, biofuels include any energy-enriched chemicals generated directly through the biological processes or derived from the chemical conversion from biomass of prior living organisms. Predominantly, biofuels are produced from photosynthetic organisms such as photosynthetic bacteria, micro- and macro-algae and vascular land plants. The primary products of biofuel may be in a gas, liquid, or solid form. These products can be further converted by biochemical, physical, and thermochemical methods. Biofuels can be classified into two categories: primary and secondary biofuels. The primary biofuels are directly produced from burning woody or cellulosic plant material and dry animal waste. The secondary biofuels can be classified into three generations that are each indirectly generated from plant and animal material. (Razzak Iet al., 2013).

The first generation of biofuels is ethanol derived from food crops rich in starch or biodiesel taken from waste animal fats such as cooking grease. The second generation is bioethanol derived from non-food cellulosic biomass and biodiesel taken from oil-rich plant seed such as soybean or jatropha. The third generation is the biofuels generated from cyano-bacterial, microalgae and other microbes, which is the most promising approach to meet the global energy demands. (Voloshin *et al.,* 2015)

In this review, we present the recent progresses including challenges and opportunities in microbial biofuels production as well as the potential applications of microalgae as a platform of biomass production. Future research endeavors in biofuel production should be placed on the search of novel biofuel production species, optimization and improvement of culture conditions, genetic engineering of biofuel-producing species, complete understanding of the biofuel production mechanisms, and effective techniques for mass cultivation of microorganisms. (Rodionova *et al.,* 2016).

The “biofuels” in this review are referred to the energy enriched chemicals generated through the biological processes or derived from the biomass of living organisms, such as microalgae, plants and bacteria. The increasing global population requests more energy supplies for improving the quality of life. Biofuels can be one of the sources to fulfill the global energy demand. Fossil fuels are being used as a main source of energy for many years; however, the usage of them is unsustainable and causes environmental issues related to fossil fuel combustion (Dragone *et al*., 2010). Hence, this challenge may allow fossil fuels to be substituted by renewable energy sources such as biofuels that is environmentally friendly (Demirbas 2009).

Biodiesel is environmental friendly (Khan *et al.,* 2005) and can be used to improve the engine performance (Gerpen 2005). It is made of non-toxic chemicals and combustion does not release sulfur and nitrogen rich flue gas as does as petrochemicals. Production of biodiesel is a simple process in two steps shown in Figure no. 6. The first step consists of the extraction of fats or oils from animal or plant tissues. The second step is trans esterification of lipid fraction with alcohols in the presence of catalysts to generate biodiesel. (Raja 2011).

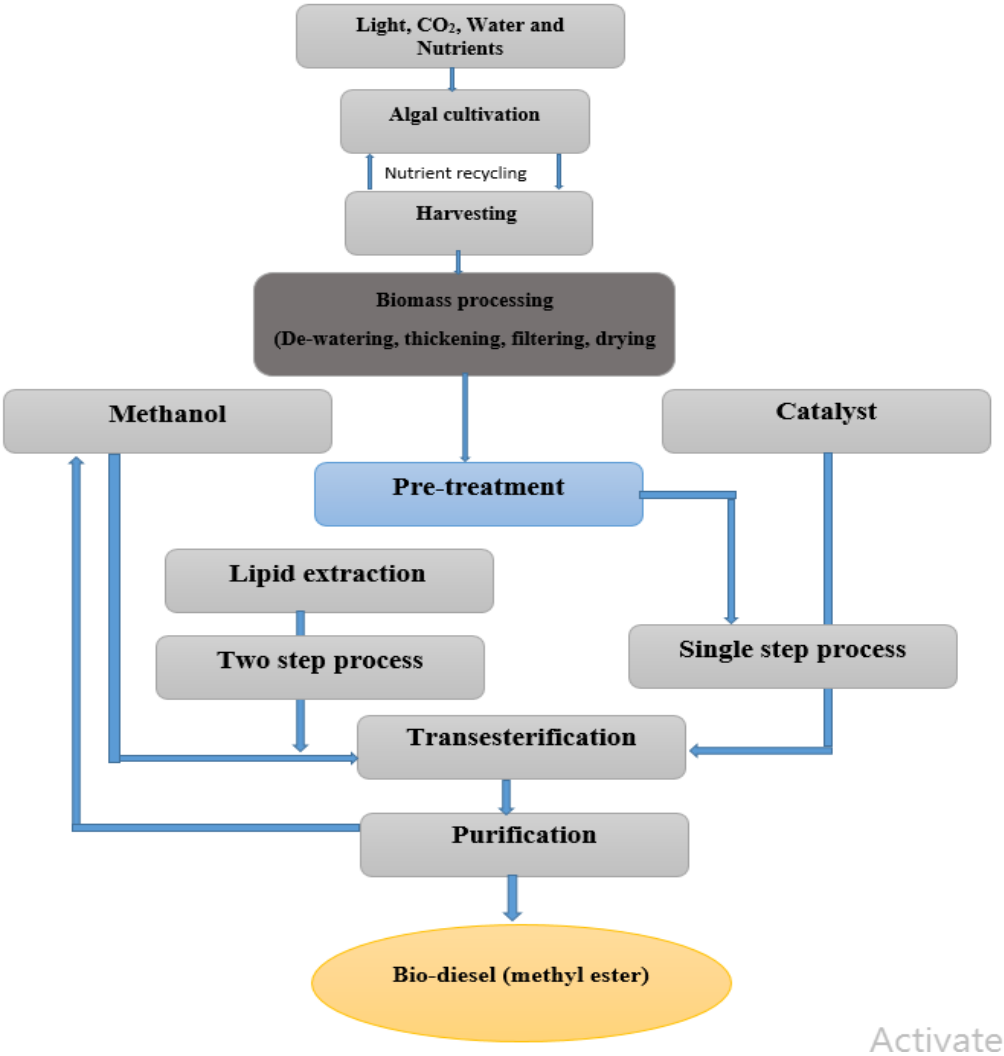

Fig 8: Bio fuels production step (Roy and Das 2015)

Efficient utilization of water in industries

Being an important natural resource, water is essential to our production and life, and critical to ecological balance. International experience suggests that water crisis may occur once a country consumes over 20% of its water resource (Demin 2000). According to National Bureau of Statistics of China, the water resource in that country totaled 3,246.64 billion m3 in 2016, 18.61% (604.02 billion m3) of which was consumed. The proportion is close to the 20% warning line. The per-capita water resource of China is 25% of the global per-capita level and 20% of that of US, ranking 121st in the world. Hence, water shortage has posed a major challenge to China.(Mortar *et al.*, 2007).

Circular utilization of water resource in primary industry:

Water resource is the lifeline of national economy and plays a leading role in agriculture. Although agricultural production mode is loosening and waste, it also decides the waste water can reversed flow into natural water cycle directly (Zou and Cong 2020). And the waste water doesn't bring serious environmental pollution. So the emphasis of water resource circular utilization in primary industry is effective utilization and economization on water. To agricultural production, water resource circular utilization follows the 4Rs - Reduce, Reuse, Recycle and Recover (Changming and Zhikai 2001). "Reduce" means reducing water consumption in order to reduce wastewater. "Reuse" means water resource is used for several times in its crude, such as, the flush water of waste material dropped by farm animals is used to irrigate farmland. It not only fertilizes the field but also avoids polluting environment; "Recycle" means the water which accomplishing its functions can be back to natural water cycle. "Recover" means waste water is classified for recovery and utilization. (Marianne *et al.*, 2010).

Water resource circular utilization in secondary industry focuses on water resource economical and intensive utilization in three layers, that is, enterprises, intra industry and industrial park. Water consumption's zero growth, which is the important direction of rational water resources utilization and management (Jun and Yizhong 2002). According the national water resource bulletins from 2000 to 2005, China's annual water consumption increasing rate is up to 9.58%. Therefore, the task is arduous to realize water resources economical and intensive utilization. Relative to the three layers, enterprises, interior industry and industrial park, they are analyzed differently in microcosmic view, in middle view and in macroscopical view, respectively.

Water resource circular utilization in tertiary Industry

In tertiary industry, the process water often mixes with the water for life. So there is no effective evaluation of water consumption and management. The water consumption of tertiary industry increases with years at present. In Shanghai, the proportion of tertiary industry water consumption is 25% in 2000 rising to 36% in last year). This indicates the shift of industry structure and the significance of researching on water resource circular utilization. Realty business is an important component in tertiary industry. And the water consumption of realty business is vast and dense. And water environment planning is made for constructing ecological residences community is as shown in Figure no.7. So it's necessary and practical to put water resources circular utilization in reality by saving water techniques. (Zhengying and Guangdou 2001).

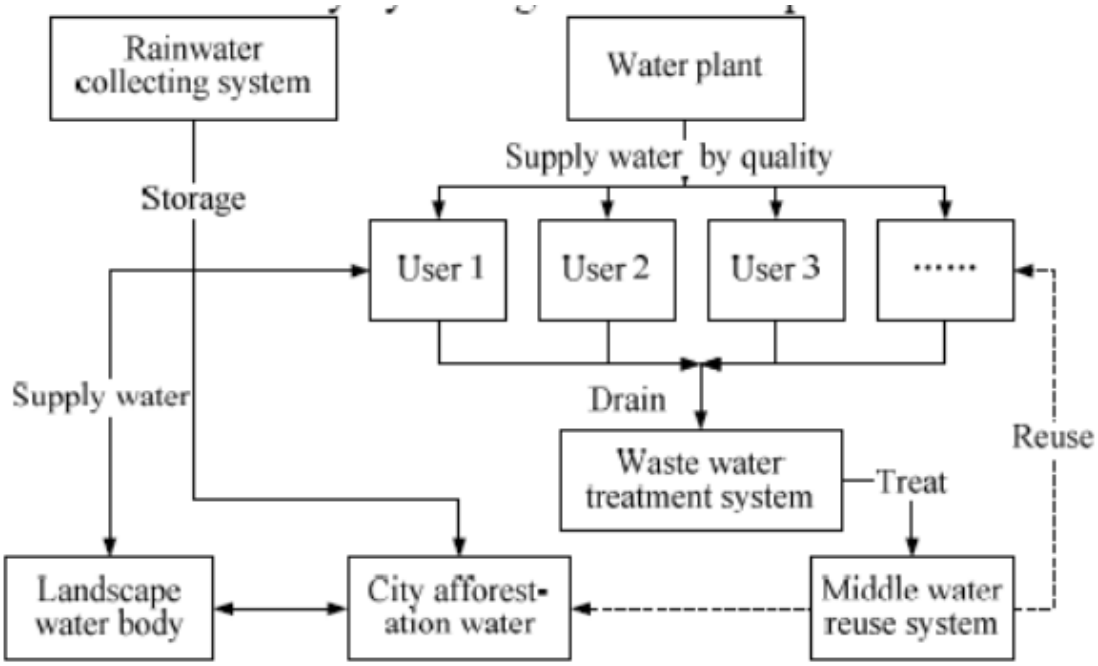

Fig 9: Water resource circular utilization mode of ecological residences community (Heng 2012)

Industry Scenario:

Renewable energy sources have a combined installed capacity of 94+ GW.

As of 31 March 2021, the total installed capacity for Renewables is 92+ GW with the following break up:

- Wind power: 39.24 GW
- Solar Power: 40 GW
- Bio-power: 10.31 GW
- Small Hydro Power: 4.79 GW

Wind energy capacity in India has increased by 1.7 times in the last 4 years. Further to this, record 100 bn+ units of renewable electricity generating last year.

Solar power capacity has increased by more than 11 times in the last five years from 2.6 GW to 28.18 GW in March 2019. Government of India further targets to increase the total Renewable Energy Capacity to 450GW by 2030.

- 42 solar parks of aggregate capacity 23,499 MW have been approved in 17 states up to March 2019
- Kurnool (1,000 MW) and Bhadla-II (648 MW) Solar Parks are fully operational
- Largest Solar Park of 2,000 MW in Pavagada is under installation (Renewable Energy in India - Indian Power Industry Investment (investindia.gov.in))

Table 5: Source-wise and State-wise Estimated Potential of Renewable Power in India as on 31.03.2019 (in MW) (National statistical office Ministry of statistics and program implementation government of India New Delhi, Energy statistics 2020.).

Sl. No.	States/ UTs	Wind Power @ 100m	Small Hydro Power	Bio-mass Power	Cogeneration - bagasse	Waste to Energy	Solar Energy	Total	Distribution (%)
1	Andhra Pradesh	44229	409	578	300	123	38440	84079	7.66
2	Arunachal Pradesh	-	2065	8	-	-	8650	10723	0.98
3	Assam	-	202	212	-	8	13760	14182	1.29
4	Bihar	-	527	619	300	73	11200	12719	1.16
5	Chhattisgarh	77	1098	236	-	24	18270	19705	1.80
6	Goa	1	5	26	-	-	880	911	0.08
7	Gujarat	84431	202	1221	350	112	35770	122086	11.12
8	Haryana	-	107	1333	350	24	4560	6374	0.58
9	Himachal Pradesh	-	3460	142	-	2	33840	37444	3.41
10	Jammu & Kashmir	-	1707	43	-	-	111050	112800	10.28
11	Jharkhand	-	228	90	-	10	18180	18508	1.69
12	Karnataka	55857	3726	1131	450	-	24700	85864	7.82
13	Kerala	1700	647	1044	-	36	6110	9538	0.87
14	Madhya Pradesh	10484	820	1364	-	78	61660	74406	6.78
15	Maharashtra	45394	786	1887	1250	287	64320	113925	10.38
16	Manipur	-	100	13	-	2	10630	10745	0.98
17	Meghalaya	-	230	11	-	2	5860	6103	0.56
18	Mizoram	-	169	1	-	2	9090	9261	0.84
19	Nagaland	-	182	10	-	-	7290	7482	0.68
20	Odisha	3093	286	246	-	22	25780	29428	2.68
21	Punjab	-	578	3172	300	45	2810	6905	0.63
22	Rajasthan	18770	52	1039	-	62	142310	162233	14.78

23	Sikkim	-	267	2	-	-	4940	5209	0.47
24	Tamil Nadu	33800	604	1070	450	151	17670	53745	4.90
25	Telangana	4244	102		-	-	20410	24756	2.26
26	Tripura	-	47	3	-	2	2080	2131	0.19
27	Uttar Pradesh	-	461	1617	1250	176	22830	26333	2.40
28	Uttarakhand	-	1664	24	-	5	16800	18493	1.69
29	West Bengal	2	392	396	-	148	6260	7198	0.66
30	Andaman & Nicobar	8	7		-	-	-	15	0.00
31	Chandigarh	-	-	-	-	6	-	6	0.00
32	Dadar & Nagar Haveli	-	-	-	-	-	-	-	-
33	Daman & Diu	-	-	-	-	-	-	-	-
34	Delhi	-	-	-	-	131	2050	2181	0.20
35	Lakshadweep	8	-	-	-	-	-	8	0.00
36	Puducherry	153	-	-	-	3	-	156	0.01
37	Others*	-	-	-	-	1022	790	1812	0.17
All India Total		**302251**	**21134**	**17536**	**5000**	**2554**	**748990**	**1097465**	**100.00**
Distribution (%)		**27.54**	**1.93**	**1.60**	**0.46**	**0.23**	**68.25**	**100.00**	

The below shown figure represents the % of electricity generated by the all the available sources.

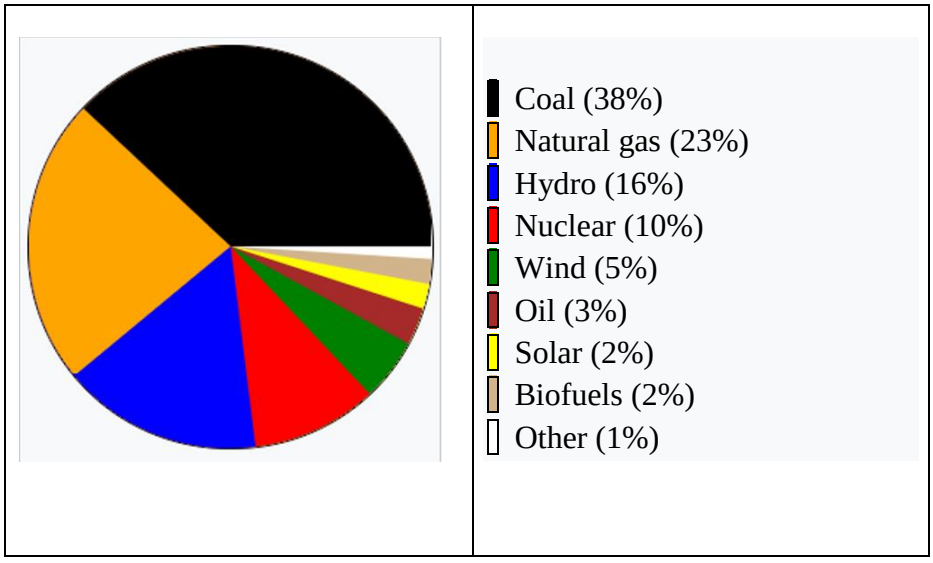

Fig 10: World electricity generation by source in 2018. Total generation was 26.7 PWh. (Wind power - Wikipedia)

Current Scenario of Conventional Energy Sources in India:

At present India is a large consumer of fossil fuel such as coal, crude oil etc. Over a past few decades, energy is needed for everything. The electricity requirement is increasing at an alarming rate due to increased population & industrial growth. This rapid increase in use of energy has created problems of demand & supply. Because of which, the future of Nonrenewable energies is becoming uncertain. India ranks sixth in the world in total energy consumption. Coming to power generation in the country, India has increased installed power capacity from 1362 MW to over 112,058 MW since independence & electrified more than 50,000 villages. This achievement is impressive but not sufficient .It is matter of concern that 44% of households do not have access to the electricity & as many as 80,000 villages are yet to be electrified. It indicates that India has had a negative Energy Balance for decades. As per 16th electric power survey, the anticipated demands require an additional 1, 00,000MW supply. In other words, the achievements of more than 5 decades need to be reproduced in the next decade. The task is overwhelming but not unachievable, because India has significant potential for generation of power from renewable energy sources. As India has a large amount of, supply of renewable energy resources, India has decided to organize a program for proper utilization of renewable energy resources. As a result of which, India is the only country in the world to have an exclusive ministry for renewable energy development, The Ministry of Non-conventional Energy Sources (MNES).

Policies of India for Renewable Energy Sources Today,

India has significant potential for generation of power from renewable energy sources. India's search for renewable energy resources that would ensure sustainable development and energy security began in early 70's of the last century. Consequently, use of various renewable energy resources and efficient use of energy were identified as the two thrust areas of the sustainable development. The few important steps taken by the Ministry of India for development of renewable Energy sources are recapitulated below. (Kumar and Meena, 2017).

- India has among the world's largest programs for renewable energy. India's activities cover all major renewable energy sources of interest to us, such as, biogas, biomass, solar energy, wind energy, small hydro power and the other emerging technologies. In each of these areas, India has programs of resource assessment, technology development and demonstration. Several renewable energy systems and products are now not only commercially available, but are

also economically viable in comparison to fossil fuels, particularly when the environmental costs of fossil fuels are taken into account.

- Realizing the need for concentrated efforts in this sector, The Government of India established a Commission for Additional Sources of Energy (CASE) in the Department of Science and Technology, in 1981. The mandate of CASE is to promote research and development activities in the field of renewable energy.
- CASE was formally incorporated in 1982, in the newly created Department of Nonconventional Energy Sources (DNES). In 1992 DNES became the Ministry for Nonconventional Energy Sources, commonly known as MNES.
- India has a vast supply of renewable energy resources, and it has one of the largest programs in the world for deploying renewable energy products and systems. Indeed, it is the only country in the world to have an exclusive ministry for renewable energy development, the Ministry of Non-Conventional Energy Sources (MNES). MNES was renamed the Ministry of New and Renewable Energy.
- India has pioneered in the world in many administrative actions of renewable energy promotion such as:-
    1. Electricity regulatory commission within liberalized market 1991
    2. Mandatory environmental audits for power projects -1992
    3. Energy conservation bill -2000
    4. Renewable Energy promotion bill- 2005.
- The Ministry is encouraging the setting up of grid-interactive power projects based on renewable energy through private investment route.
- The State Nodal Agencies are responsible for promotion and development of private sector projects by way of providing necessary clearances, allotment of land, allotment of potential sites in case of SHP projects and facilitating power purchase agreements etc.
- State Electricity Regulatory Commissions (SERCs) are determining tariffs by taking into account the submissions of all stakeholders, including consumers.
- A number of leading financial institutions and banks are financing renewable energy based power.

Zero Liquid Discharge

In the past multiple decades, industrial production has enlarged because of an increasingly open economy and a significant emphasis on industrial development and international trade. Water utilization for industrial use has consequently risen and will continue to rise up. So an ecological issues are an integral and important part of the environmental issues challenging India. Poor air quality, water pollution, and garbage all affect the quality of food and the environment necessary for ecosystems to thrive where it affect the environmental sustainability, India is recognized as having major issues with water pollution, predominantly because of untreated industrial wastewater and failure to achieve zero liquid discharge(ZLD) (Shrikant Ahirrao,. 2014 ZLD). Zero liquid discharge (ZLD) is Defined as Systems that seek to eliminate wastewater discharge from any given process are known as Zero Liquid Discharge (ZLD) systems (Sabla Y,. 2019).

Or

It implies that wastewater is treated and effectively recycled and reused such that there is no effluent discharge. ZLD is usually accomplished by concentrating the effluent using various techniques, including membrane-based and multi effect evaporation based systems.

ZLD involves:

- The elimination of the liquid waste effluent stream from the plant
- The recycling of recovered water and solids
- The establishment of no liquid pollutant norms.

Through reuse, wastewater is no longer considered a “pure waste” that potentially harms the environment, but rather an additional resource that can be harnessed to achieve water sustainability. It has been suggested that ZLD can be accomplished by following the water minimization hierarchy (WMH) (Yaqub,. 2019)shown in Fig. 1.

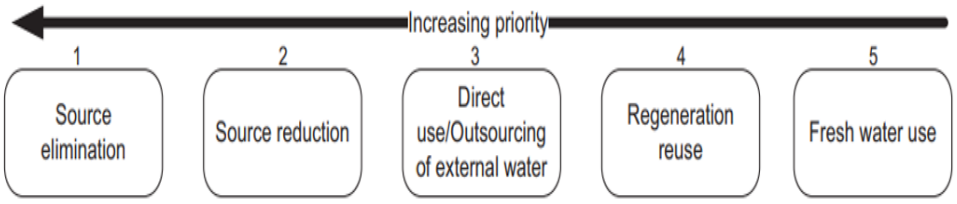

Fig 11. Block diagram of the water minimization hierarchy (WMH). Source (Alwi et al., 2008).

Table 6: Merits and De-merits of ZLD is mentioned below

Merits	De-merits
• No impact on surrounding soil salinity, groundwater pollution or ecology of river bodies • Conservation of water resource through recovery and re-use of treated effluent • Recovery and re-use of salt used in the textile dyeing process	• Use of higher amount of chemicals in wastewater treatment • Increase in energy usage • Generation of enormous amount of hazardous sludge and other solid waste Impact on cost of processing (implementing ZLD pushes up costs by 25-30%

In achieving ZLD:

Where in sustainability development in order to achieve Zero Liquid Discharge, we have to recover the salt and water separately from the effluent and then reuse it in the dyeing process. This is a very complicated, tedious and expensive process, in view of investment, operating and maintenance costs. We also need to apply lot of chemistry, engineering & technology know-how.

As a simple explanation, the effluent is treated in an Effluent Treatment Plant (ETP) comprising Primary, Secondary and Tertiary Treatment steps. The treated water is recovered from the Reverse Osmosis Plant (RO) process during tertiary treatment phase and Salt is then recovered by using Multiple Effect Evaporation (MEE) with Crystallization. (Karaghouli,.2013)

There is also a water loss in the treatment process and hence only about 80- 85% of the water can be recovered and re-used back in the process. The cost of this recovered water recycled into the process is always much higher than the cost of input water used from other sources. But if ZLD is viewed from an ecological, social and environmental viewpoint – and not as a Cost Centre – then it merits implementation at all factories with no access to a Common Effluent Treatment Plant.

In recent years, greater recognition of the dual challenges of water scarcity and pollution of aquatic environments has revived global interest in ZLD. More stringent regulations, rising expenses for wastewater disposal, and increasing value of freshwater are driving

ZLD to become a beneficial or even a necessary option for wastewater management. The global market for ZLD is estimated to reach an annual investment of at least $100−200 million, spreading rapidly from developed countries in North America and Europe to emerging economies such as China and India.

Early ZLD systems were based on stand-alone thermal processes, where wastewater was typically evaporated in a brine concentrator followed by a brine crystallizer or an evaporation pond. The condensed distillate water in ZLD systems is collected for reuse, while the produced solids are either sent to a landfill or recovered as valuable salt byproducts. Such systems, which have been in successful operation for 40 years and are still being built, require considerable energy and capital (Tiezheng Tong-2016).

Design Considerations

The following design factors are to be considered when planning a zero discharge system:

- Temperature
- Salt concentration
- Organic cut
- Crystallization methodology.

The above parameters are first analyzed in the laboratory, and the feasibility of the process is studied, ultimately leading to the selection of processes and the understanding of recovery aspects.

Components of ZLD

- Effluent pre-treatment—filters and clarifiers
- Effluent COD/BOD reduction—biological treatments
- Effluent volume reduction—membranes
- Effluent concentration—evaporation
- Solids separation and discharge—centrifuge and drying
- Treatment of recovered water through distillation and membrane separation.

How ZLD supports sustainability?

A water audited system used in combination with the WMH can help determine appropriate measures for water conservation. But ZLD is more likely to be achieved by considering inputs, outputs, and water quality, rather than aiming to minimize wastewater outputs only (Barrington and Ho,. 2014). The following figure shows that how ZLD can be help in the environmental sustainability development.

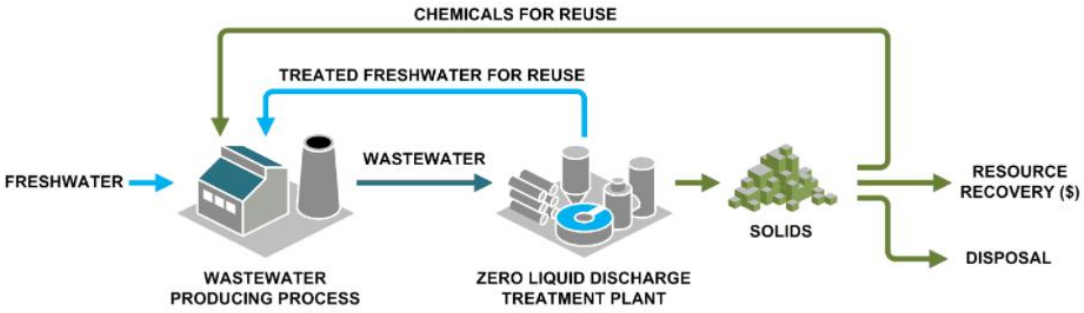

Fig 12: Showing the pictorial representation of how the ZLD helps in environmental sustainability. (Zero Liquid Discharge - Bing images)

There are a number of benefits to targeting zero liquid discharge for an industrial process or facility:

- Lowered waste volumes decrease the cost associated with waste management.
- Recycle water on site, lowering water acquisition costs and risk. Recycling on-site can also result in less treatment needs, versus treating to meet stringent environmental discharge standards.
- Reduce trucks associated with off-site waste water disposal, and their associated greenhouse gas impact and community road incident risk.
- Improved environmental performance, and regulatory risk profile for future permitting.
- Some processes may recover valuable resources, for example ammonium sulfate fertilizer or sodium chloride salt for ice melting (www.saltworks.com).

Wastewater treatment plants (WWTP) such as the zero liquid discharge can be installed mainly in the industries, as industries were prescribed to install the wastewater treatment plant, Effluent treatment plant (ETP), common effluent treatment plant and including sewage treatment plant (STP), all these systems could install this zero liquid discharge system

As this study says in different platforms the ZLD can perform, those platforms are briefed bellow for the sake of knowledge.

Sewage treatment plant (STP): The process of removing contaminants from municipal wastewater, containing mainly household sewage plus some industrial wastewater. Physical, chemical, and biological processes are used to remove contaminants and produce treated wastewater that is safe enough for release into the environment. The sewerage project in respect of which considerable public and social resources are being used, form a basic infrastructure for the country and an indisputable indicator of civilization and development. The works cover a number of substantial social needs and aim to improve the quality of life and to protect public health and the environment. (www.netrix.in).

Instead of discharging the treated water to the nearby streams, that water could be used by the industry may lead to save the source of fresh water needed by the industry. The typical complete STP process is depicted in the below figure.

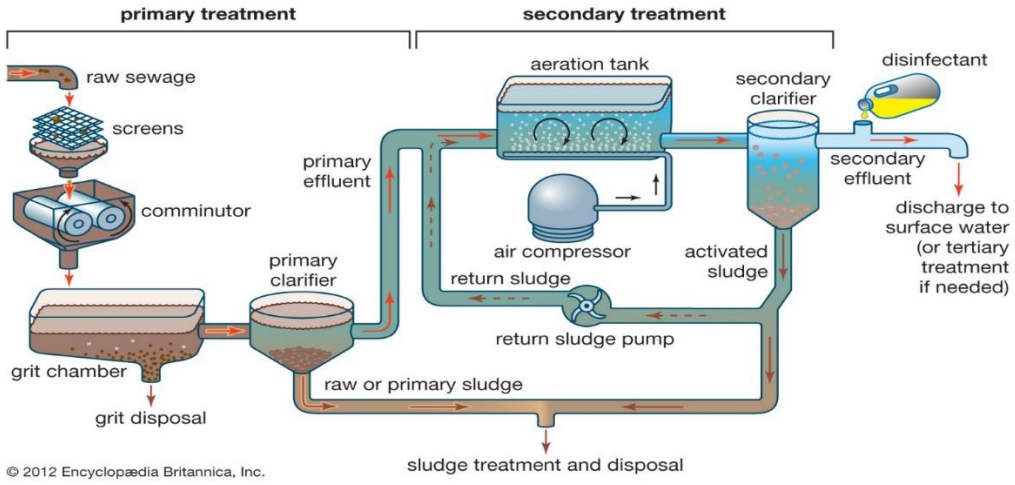

Fig 13: Sewage Treatment Plant (sewage treatment plant diagram - Bing images)

Effluent Treatment Plant (ETP): ETP is one type of waste water treatment method which is particularly designed to purify industrial waste water for its reuse and its aim is to release safe water to environment from the harmful effect caused by the effluent.

Industrial effluents contain various materials, depending on the industry. Some effluents contain oils and grease, and some contain toxic materials (e.g., cyanide). Effluents from food and beverage factories contain degradable organic pollutants. Since industrial waste water contains a diversity of impurities and therefore specific treatment technology called ETP is required.

The ETP Plant works at various levels and involves various physical, chemical, biological and membrane processes to treat waste water from different industrial sectors like chemicals, drugs, pharmaceutical, refineries, dairy, ready mix plants & textile etc.

The treated water from ETP is discharged to nearby streams, but there is problem with this discharging so the water can be used with in the industry after treatment, and hence the fresh water demand by the industry can be reduced, and the efficient usage of waste water after treatment can be achieved. The following figure shows that the complete mechanism of how an Effluent treatment plant works (Amutha,. 2017)

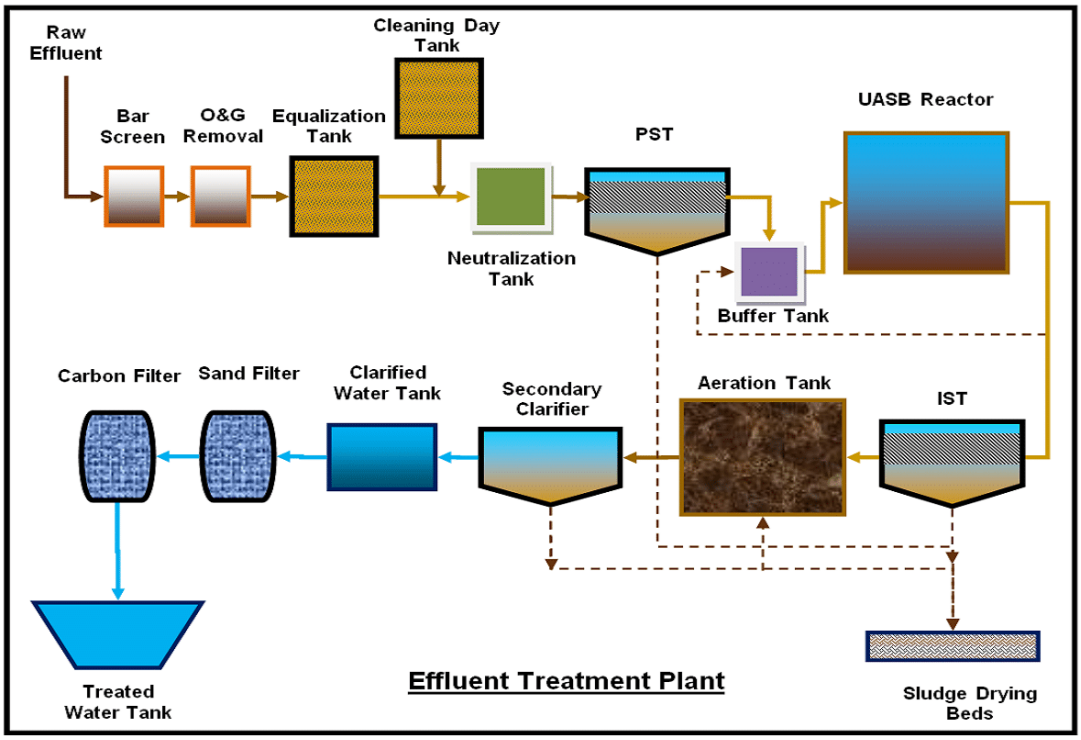

Fig 14: Effluent Treatment Plant (Effluent Treatment Plant Diagram - Bing images)

Common effluent treatment plant: Effluent treatment plant is essential to purify the waste water which is come from different types of manufacturing industry like textile, tannery, dyes and chemical manufacturing industry, pharmaceuticals etc. Different environment saving organizations are trying to protect the environment from the harmful effect of the effluent. Different waste water has different characteristics which pollute the water. (Onishi,. 2019)

Common Effluent Treatment Plant is the concept of treating effluents by means of a collective effort mainly for a cluster of small scale industrial units. This concept is similar to the concept of Municipal Corporation treating sewage of all the individual houses. The main objective of CETP is to reduce the treatment cost for individual units while protecting the environment.

- To achieve 'Economics of scale' in waste treatment, thereby reducing the cost of pollution abatement for individual factory.
- To minimize the problem of lack of technical assistance and trained personnel as fewer plants require fewer people.
- To solve the problem of lack of space as the centralized facility can be planned in advance to ensure that adequate space is available.
- To reduce the problems of monitoring for the pollution control boards.
- To organize the disposal of treated wastes and sludge and to improve the recycling and reuse possibilities. (Maheswari,. 2000).

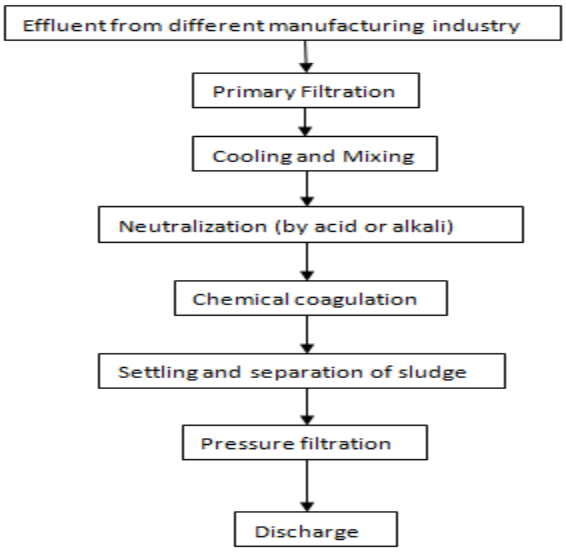

Fig 15: Basic flow chart of Common Effluent Treatment Plant (design-of-effluent-treatment-plant-5-638.jpg

Reverse osmosis is one of the main process used in the ZLD system

RO-incorporated thermal ZLD systems

In this system, RO, a well-established, pressure driven desalination technology is combined with thermal ZLD systems to decrease the volume of brine slurry entering the brine concentrator or crystallizer, thereby lowering the energy consumption is as shown in(Fig. 3). The energy consumption by RO for 50% recovery in the desalination of seawater is around 2 kWhe/m3 of product water (Phillip,. 2011), which is much lower than for brine concentrators and crystallizers. This type of system is economical if RO-fed wastewater has a lower salinity (Kazmerski,. 2013), typically up to 70,000 mg/L (Shaffer., 2013), while the availability of newly developed membranes indicates further opportunities to apply RO in wastewater treatment. Wastewater is therefore concentrated by RO before entering to thermal processes, minimizing capital and operational costs. As reported in previous studies, using RO to treat brine in a desalination plant conserves around 58–75% of energy and 48–67% of treatment costs compared to a brine concentrator-evaporation pond setup (Veerapaneni,. 2007, 2008).
The application of RO has a salinity limit, however, and fouling problems that decrease water flux and the lifespan of membranes in ZLD systems are also an issue. Therefore, various techniques can be employed during pretreatment including chemical softening, pH adjustment, and ion exchange.

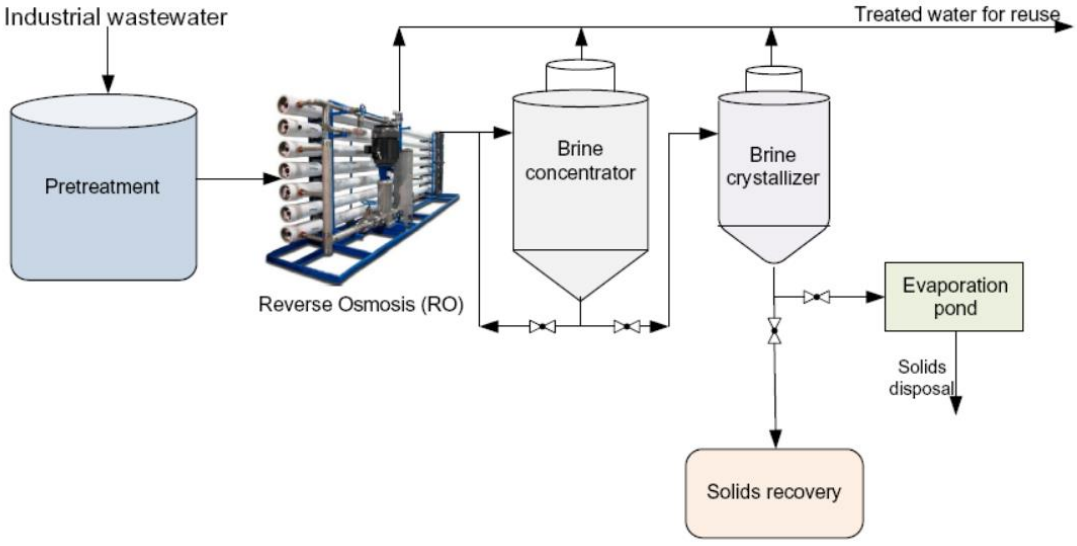

Fig 16: Schematic diagram of an RO-incorporated ZLD system. (Yaqub,. 2019)

What is Reverse Osmosis (RO)?

Reverse osmosis is a membrane treatment process primarily used to separate dissolved solutes from water. Reverse osmosis is most commonly known for its use in drinking water purification particularly with regard to removing salt and other effluent materials from water molecules.

How does Reverse Osmosis work?

An easy experiment can be conducted taking some freshwater and a concentrated aqueous solution. The solutions should be kept on opposite sides with a semipermeable membrane placed in between to separate the two solutions. Pressure should be applied on the side with the concentrated solution. Now this will result in water molecules moving through the membrane to the freshwater side. This basically sums up the process of reverse osmosis. The below shown figure represents the reverse osmosis process (Zueva,.02019)

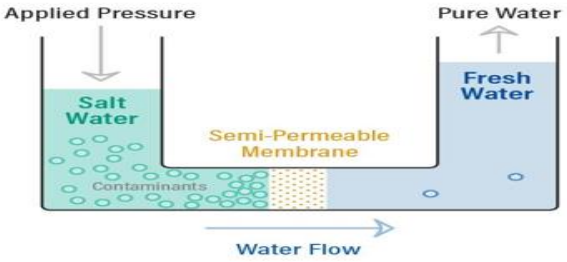

Fig 17: Reverse osmosis (Reverse Osmosis - Bing images)

Table 7: Below we have discussed some of the benefits of STP, ETP, CETP and RO.

STP	1. Upgrading the quality of life, 2. Preserving the natural environment, 3. Saving and processing waters, 4. Saving of money, 5. Economic development and tourism, 6. Flooding incidences and Standard of living.
ETP	1. To clean industry effluent and recycle it for further use 2. To reduce the usage of fresh water in industries 3. To preserve natural environment against pollution 4. To meet the standards for emission of pollutants set by the Government & avoid heavy penalty 5. To reduce expenditure on water acquisition

CETP	1. Saving in capital and operating cost of treatment plant. The common treatment is always cheaper than small scattered treatment units. 2. Professional trained staff can be made available for operation of CETP which is not possible in case of individual plants. 3. The neutralization and equalization of heterogeneous waste makes its treatment techno-economically viable. 4. Disposal of treated waste water and sludge becomes more organized
RO	1. This process can be used to effectively remove many types of dissolved and suspended chemical particles as well as biological entities (like bacteria) from the water 2. This technique has a wide application in treating liquid wastes or discharge 3. It is used in purifying water to prevent diseases 4. It helps in the desalinating seawater 5. It is beneficial in the medical field.

As per the government policies with respect to industries in order to achieve zero liquid discharge they are mentioned below.

Ministry of Environment and Forest (MoEF), the government of India has issued a draft notification to control the massive pollution caused by the textile industry. It has directed the industry players to adhere to the 'Zero Liquid Discharge' (ZLD) norms which make it mandatory for them to recycle all effluents released by the factories.

According to the draft notification,

- All textile units – dyers, cotton or wool processors, integrated factories – that generate over 25 kilo litre effluents daily must install Zero Liquid Discharge effluent treatment plants.

- Textile units in industrial parks have to set up Zero Liquid Discharge (ZLD) – Common Effluent Treatment Plants (CETPs) and augment all the current CETPs into Zero Liquid Discharge (ZLD) – Common Effluent Treatment Plants (CETPs)

- Water recycled by these plants will be reused. The water should be recovered by using Effluent Treatment Plant (ETP), Reverse Osmosis (RO), and Multi Effect Evaporator (MEE)The units won't be allowed to draw groundwater except to make up for the shortfall and for drinking, as assessed by the respective State Pollution Control Board or the Pollution Control Committee.

- After the notification is approved, the units will have 30 months to set up the treatment plants. They won't be allowed to operate if they fail to comply. The units that already have effluent treatment plants will be required to make them ZLD compliant. Until upgraded to ZLD, the existing treatment plants will follow the "effluent discharge standards as specified in the Environment Protection Rules, 1986".

The below map showing that that the zero liquid discharge system market- growth rate by region from the Mordor intelligence source, from 2019 to 2024, as represented in the picture the color green shows that there is high growth rate in those region, color yellow shows the medium growth rate and color red showing that the low growth rate of ZLD system marketing

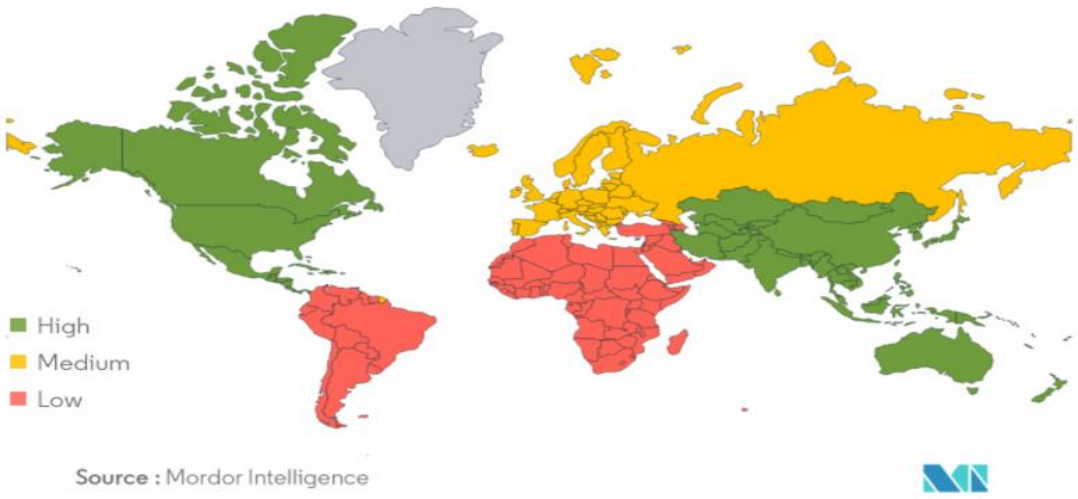

Fig 18: Zero liquid discharge system market – Growth rate by region, 2019-2024 (Zero Liquid Discharge System Market – Global Industry Trends and Forecast to 2026 | Data Bridge Market Research)

Technical Route for Achieving ZLD

ZLD can be achieved by adopting conventional primary, secondary and tertiary effluent treatment and polishing by filtration and using clean water back into process / or domestic use. In some case, Reverse Osmosis, micro/nano filtration and concentrating with multiple effect evaporators (MEE) can be employed. It has been quite often debated that employing ZLD route is energy intensive and having exorbitant cost / financial burden. But, it cannot be denied that in the present circumstances when ground water table is getting depleted and there is diminishing flow in rivers, permitting industries to discharge even treated effluents, does not seems to be environmentally acceptable proposition. However, industries will be at their technical wisdom and expertise to search for better ZLD achieving practice but with a caution that there will stern actions if, on the name of ZLD, un-acceptable practices are adopted. (ww.CPCB.com)

ZLD can help in direct reuse of treated wastewater with in industry

A business can directly reuse wastewater that is clean enough for the purpose for which it is being reused. Process water is produced by industrial processes such as cooling and heating, and often contains few contaminants after use. In industry, both rainwater and process water can be reused for purposes such as:

- Irrigation (https://www.who.int/water_sanitation_health/publications/gsuweg4/en/)
- Washing
- pH adjustment
- Fire protection

Industrial symbiosis can take place in three ways:

- Exchange of by-products,
- Sharing the management of utilities, and
- Sharing ancillary services.

Some possibilities for decentralized wastewater treatment systems include:

- Waste stabilization ponds
- Aerated ponds
- Constructed wetlands (see free-surface, horizontal, vertical, and hybrid constructed wetlands)

- Non planted filters
- Technologies making use of anaerobic digestion such as: anaerobic baffled reactors, biogas settlers, and anaerobic digestion

More high-tech options: activated sludge, membrane bioreactors, advanced oxidation processes, ozonation, activated carbon, rotating biological contactors.

Conclusion and Way Forward

1. The industries having high organic load and other refractory nature of pollutants will be requiring to adopt ZLD system.
2. ZLD would refer to a system which would enable and industry to recover clean water using back into industrial processes or domestic use and not subjecting to be disposed in ambient environment including use in industrial premises.
3. Industries will have options to select technical system facilitating to achieve ZLD.
4. Industries will face closures for long-time if found violating the prescribed standards and having installed on-line effluent monitoring devices and data will be available with regulatory bodies and also in public domain.
5. Sectors like Pulp & Paper will immediately adopt charter which will facilitate them to reduce pollution load and maximize reduction in water usage / consumption as well as reducing in quantity of effluent disposed. However, such industries shall be subjected to for regular vigilance and followed by stern action in case of their non-compliance to the existing stipulated / verified standards. (Source: CPCB).

Rain Water Harvesting

Like other living organisms man cannot survive without water. Rainwater Harvesting is being practiced from the birth of human civilization. During the twentieth century the use of rainwater harvesting techniques declined around the world, partly due to the provision of large, centralized water supply schemes such as dam building projects, ground water development and piped distribution systems among others. Currently RWH enjoying a revival in popularity due to the inherent quality of rainwater and interest in reducing consumption of treated water. Rainwater is valued for it's purity and softness. It has a nearly neutral pH, and is free from 1 by-products, salts, minerals, and other natural and man-made contaminants. It makes use of natural resource and reduces flooding, storm water runoff, erosion, and contamination of surface water with pesticides, sediment, metals, and fertilizers. Rainwater collected immediately after precipitation is the purest of all natural waters. It may contain traces of gases dissolved out of the atmosphere and possibly a small amount of finely divided solid matter derived from the air. In towns rain may collect dissolved or suspended impurities such as soot, traces of sulfur dioxide or sulphuric acid and other by product of industrialization (Vesilind, 1991).

Rainwater harvesting (RWH) can be defined as the collection, conveyance, and storage of rainwater for an intended use. Roof Rain Water Harvesting (RRWH) is the practice of capturing the rainfall from roofs, diverting it through gutters and drains, and storing the water in tanks of various sizes for later use. (Malesu *et al.*, 2006).

Rainwater may be collected from any kind of roof. Tiled or iron sheets are easier to use and produce main criteria for such water are : Freedom from suspended solids that can give staining in processing, No great excess of acid or alkali, I. e. pH range of +2 or -2 on either side of neutral point, and freedom from substances affecting the textile processes, such as Iron, Manganese, Calcium and Lead (Little, 1975).

Benefits of setting up of a Rain Water Harvesting system in Industries

- The water bill is a huge expense for any industry. And it is difficult to cut back the usage of water. Installing a rainwater harvesting system leads to 80% direct cost saving on lengthy water bills.
- It is sometimes perceived that the installation of an RWH system is an additional expense. But if you consider its future returns, the system pays for itself over a 3 to 5 years period, majorly through cost savings on water usage.
- Most of the industries have to run methods to avail freshwater, for the personnel and industrial functional use. These methods involve filtration pumps, which are responsible for emitting carbon into the environment. Rainwater harvesting system guarantees the availability of freshwater, thus cutting down on one's carbon footprints by saving the power used in freshwater processing.
- As mentioned earlier, the commercial centers have bigger catchment areas. This means they have high potential to receive a large amount of rainwater. Instead of

losing such precious drops to the drains, the rainwater harvesting system can collect and store them, for those times of desperate needs.

- Water recycling systems installed in industries and offices also get benefited by a rainwater harvesting system, as they will receive better quality, thereby increasing their shelf life.
- Harvested rainwater is naturally soft and is found in its purest form. This leaves your storage tanks with high quality water, having a minimal requirement for filtration. (Akumu, 2006)

Commercial Uses

The commercial use of rainwater harvesting systems, it generally meant using the harvested water for non potable purposes. Here are some uses of harvested rainwater, in a commercial setup:

- Making up a cooling tower
- Toilet flushes
- Irrigational purposes
- Suppression of Fire in case of accidents
- Manufacturing processes for business products
- Vehicle /Fleet washes
- Laundries
- Filling up the pool

Legislation's for Rainwater Harvesting in India

The Central and State government in India are extending their support to make the practice of rainwater harvesting a success. Along with the initiatives like Rainwater Harvest Challenge, many state authorities have made it a mandate for commercial and residential buildings to have rainwater harvesting system, under certain norms.

In Indore, Madhya Pradesh, all new buildings with an area of 250 Sq. Meter or more must have RWH system installed.

Similarly, the construction companies and owners of the commercial buildings in other states have to make provision for setting up RWH system based on state specific building area mandate – buildings having 1000 Sq. Meter plinth area in Himachal Pradesh, Kanpur and New Delhi. And so on.

In certain states, a rebate of 6% on property tax has been offered to all the owners having rain water harvesting systems installed on their building.

In the state of Maharashtra, a 5% rebate is provided in general tax, under the pretext of rainwater harvesting. (Diana Starovoytova, 2016).

Fig 19: Rainwater Harvesting System

Rainwater Harvesting Systems consists of the following components:

- Catchment – Used to collect and store the captured Rainwater.
- Conveyance system – It is used to transport the harvested water from the catchment to the recharge zone.
- Flush – It is used to flush out the first spell of rain.
- Filter – Used for filtering the collected Rainwater and remove pollutants.
- Tanks and the recharge structures – Used to store the filtered water which is ready to use.

The process of rainwater harvesting involves the collection and the storage of rainwater with the help of artificially designed systems that run off naturally or man-made catchment areas like – the rooftop, compounds, rock surface, hill slopes, artificially repaired impervious or semi-previous land surface. (Walton *et al.*, 1995)

Several factors play a vital role in the amount of water harvested. Some of these factors are:

- Rainfall quantity
- The quantum of runoff
- Features of the catchments
- Impact on the environment
- Availability of the technology
- The capacity of the storage tanks
- Types of the roof, it's slope and it's materials
- The frequency, quantity and the quality of the rainfall

Rainwater Harvesting Methods

1. **Roof Rain Water Harvesting**

Rooftop Rain Water Harvesting is the technique through which rain water is captured from the roof catchments and stored in reservoirs.

2. **Land based Rain Water Harvesting**

Land based rainwater harvesting occurs when runoff from land surfaces is collected in furrow dikes and ponds.

3. **Watershed based Rain Water Harvesting**

Direct falling rainwater can be stored in a reservoir formed due to construction of dams across a stream, check dams constructed across the streams or ponds. This is called Watershed based RWH.

Rainwater harvesting is the most traditional and sustainable method, which could be easily used for potable and nonpotable purposes both in residential and commercial buildings. This could reduce the pressure on processed supply water which enhances the green living. Rainwater harvesting should be improved to gain sustainability in various aspects in rural as well as in urban areas. In densely populated countries like India, the demand for water goes on increasing with increase in population. Hence it is necessary to adopt rain water harvesting.

Green Belt Development

Green belt is plantation of trees for reducing the pollution as they absorb both gaseous and particulate pollutant, thus removing them from atmosphere. Green plants form a surface capable of absorbing air pollutants and forming sinks for pollutants, it improves the aesthetic value of local environment. Green belts are planned open spaces safeguarded from developmental activities such as construction of buildings, factories, any other infrastructural activities, these are used only for growing vegetation cover. Green belts in and around urban and industrial areas are important for maintaining ecological health of the region.

The purpose of a green belt around the industrial site is to capture the fugitive emissions, attenuate the noise generated and improve the aesthetics.

For example, if the industry has been proposed in an area of about 1.2265 hectares that is 12265 sq. m. Out of 12265 sq. m of total land available about 4019.5 sq. m for built up area like production blocks, raw material stores, finished goods, utilities, R&D, administrative block and pollution control facilities. About 1550 Sq. m for Roads, 2395.5 Sq. m for vacant area and 4300 sq. m greenbelt area. (Vijay Kumar *et al*., 2019)

Sitting guidelines for industries

The MoEFCC has notified siting criteria for establishment of industries considering and striking balanced approach between economic, social and environmental factors into consideration. The factors related to green belt are given below. (Handbook of Environmental Procedures and Guidelines, 1994)

- The green belt shall be 1/2km wide around the battery limit of the industry, for industry having odour problem it shall be one km wide.
- The green belt between two adjoining large scale industries shall be one km.
- No prime agricultural land shall be converted into industrial site.
- No forest land shall be converted into non-forest activity for the sustenance of the industry (FCA, 1980).
- Land acquired shall be sufficiently large to provide space for appropriate treatment of wastewater, the treated wastewater left after maximum possible reuse and recycle should be used to raise green belt and to create water body for aesthetics, recreation and if possible for aquaculture.

Conditions related to green belt cited in standard terms of reference issued by MOEFC (2015)

The MoEFCC has notified the EIA Notification, 2006 under the provision of the Environment (Protection) Act, 1986, which regulates development and their expansion/modernization of 39 sectors / activities listed in the schedule to the EIA Notification, 2006. There are two category of the projects viz. Category A projects are handled at the level of MoEFC and the Category B projects are handled by the respective State Environment Impact Assessment Authority (SEIAA) following the procedure prescribed under the EIA notification, 2006. For obtaining EC the EIA report has to be prepared based on the Standard Terms of reference (ToR)**.**

Some of the guidelines to be considered are :

a) Planting of trees in each row will be in staggered orientation.
b) In the front row, shrubs will be grown.
c) Since the trunks of the tail trees are generally devoid of foliage, it will be useful to have shrubs in front of the trees so as to give coverage to this portion.
d) The spacing between the trees will be maintained slightly less than the normal spaces, so that the trees may grow vertically and slightly increase the effective height of the green belt.
e) Providing the Greenbelt more than 33% area of the total project area with various species.

Advantages of Green Belt Development:

- The biological activity of the particles at various locations necessarily vary because of different of pollutant source profiles. These variations are expression of both quantitative and qualitative differences, as for instance the relative amount of sulfuric acid mist, sulfates, or other reactive substances in the particulate mix or the relative amounts of specific carcinogenic compounds in the organic fraction of airborne particulate.
- It, therefore, can be seen that the evaluation of biological activity ascribable to "particulate" is complex and depends not only on the total quantity, size range and intrinsic physical or chemical properties, but also on their chance for interaction in the polluted air. The opportunity for variation in biological activity is enormous.
- Stomata are microscopic pores on the underside of the leaf. These stomata allow the plant leaves takes in Carbon dioxide and let's out Oxygen, and also allows water vapor out in the process of transpiration. As air passes through the stomata,

most of the airborne particles will not pass through the stomata but will rather land on the leafs outer surface.

- This is similar to a filter, where air is pulled through the filter by an air pump and the airborne particles deposit on the filter surface. If this air flow is the major cause of particles depositing on the leaf, the result will be that the concentration of particles on the abaxial surface of the leaf will be higher than that of the top surface because the airflow through the stomata will be pulling more particles onto the bottom surface.
- Trees can delimit the fine particulate pollution and have tremendous potential for improved air quality with substantial cost savings. This study will help to quantify the relative ability of individual tree species for removing fine particulates such as PM25. The plantation of urban trees can be evaluated in terms of money saved vis-à-vis expenditure involved in implantation of fine particulate strategies.
- Trees can act as efficient biological filters, removing significant amounts of particulate pollution from urban atmosphere. The study indicated that there has been significant difference in interception of particulate matter (PM2.5) by different tree species.

Development of Green belt

Most of the anthropogenic activities generate poll in one or other types and of different magnitude, for which all the organisms are exposed. In such cases the green belts will be effective in controlling the pollution. Leaves with their vast area in a tree crown, sorbs pollutants on their surface, thus affectively reduce their concentrations in ambient air. Often the sorbed pollutants are incorporated in metabolic stream and thus the air is purified. Plants grown in such a way as the function as pollutant sinks are collectively referred as green belts. As per guidelines for development of greenbelts, CPCB (programme objective series – PROBES/75/1999-2000) there are two types of approaches for designing green belts viz. 1) source oriented and 2) receptor oriented.

Source oriented approach is advantageous where a single industry is situated and the pollutants emitted by the same are sought to be contained. The receptor oriented approach is desirable in urban / industrial complexes with multiple sources of pollution are present along with human settlements in between.

While making choice of plant species for cultivation in green belts, weightage has to be given to the natural factor of bio-climate, authorities responsible for plantation should make adequate provisions for watering and protection of the saplings. For effective removal of pollutants following measures has to be adopted.

- See the plants grow under conditions of adequate nutritional supply (for health and vigour of growth)
- Absence of water stress (to maintain openness of stomatal apertures and form of epidermal structures)
- Plants are well exposed to atmospheric condition of light and breeze to maintain free interaction with gases.

Table 8: Characters of plants

For absorption of gases	For removal of suspended particulate matter
Tolerance towards pollutants	Height and spread of crown
Longer duration of foliage	Leaves supported on firm petioles
Freely exposed foliage, through • Adequate height of crown, • Openness of foliage in canopy, • Big leaves large number of stomatal apertures, • Stomata well exposed	Abundance of surfaces on bark and foliage through • Roughness of bark, • Epidermal outgrowths on petioles • Abundance of axillary hairs • Hairs or scales on laminar surfaces • Stomata protected

The plant foliage plays a major role in absorbing air pollutant efficiently, due to the favorable light conditions near the canopy surface of the plant. (Vijay Kumar *et al.*,2019).
The width of the green belt varies based on the type /category of industry as given by,

Table 9: Width of the green belt based on industry type

Class	Industry	Width of GB (m)
1	Heavy industry with high potential of air pollution	>500
2	Heavy industry with low potential of air pollution	200 to 500
3A	Medium heavy industry with high potential of air pollution	100 to 200
3B	Medium heavy industry with low potential of air pollution	100 to 200
4A	Light industry with high potential of air pollution	50 to 100
4B	Light industry with low potential of air pollution	50 to 100
5	Service industry	10 to 50
6	Workshops, handicrafts, etc.	<10

Source: (Gupta *et al.*, 2008)

Development of Green belt cover is beneficial in many ways leading to conservation of biodiversity, retention of soil moisture, recharge of ground water and maintaining pleasant climate of the area, providing possible habitats for birds and animals. The main advantages of green belt in and around the industry are to control air and noise pollution. Green belt also helps in soil erosion control through improvement of soil quality and binding soil particles, it also contain water run offs and improves ground water infiltration and improves ground water recharge capacity. The green belt species should be selected based on the type /category of the industry and climatic conditions.

Air Pollution Control Measures

As the number of humans on earth increases, our agricultural and industrial activities have a greater impact on the environment, particularly on the atmosphere. The Industrial Revolution was the progress to new manufacturing measures in Europe and the United States, in the period from between 1760 to 1820 and 1840. This change included going from hand creation techniques to machines, new substance assembling and iron creation measures, the expanding utilization of steam force and water power, the advancement of machine devices and the ascent of the automated processing plant framework. The Industrial Revolution additionally prompted a phenomenal ascent in the pace of populace development. Textiles were the prevailing business of the Industrial Revolution as far as work, worth of yield and capital contributed. The material business was likewise quick to utilize current creation methods (Anthony et al.,).

The Industrial Revolution started in Great Britain, and a significant number of the mechanical advancements were of British origin. By the mid-eighteenth century Britain was the world's driving business nation, controlling a worldwide exchanging domain with provinces North America and the Caribbean, and with significant military and political authority on the Indian subcontinent, especially with the proto-industrialized Mughal Bengal, through the exercises of the East India Company. The improvement of exchange and the ascent of business were among the significant reasons for the Industrial Revolution.

The Industrial Revolution denotes a significant defining moment ever; pretty much every part of day by day life was affected here and there. Specifically, normal pay and populace started to display uncommon supported development. A few financial analysts have said the main impact of the Industrial Revolution was that the way of life for everyone in the western world started to increment reliably without precedent for history, despite the fact that others have said that it didn't start to definitively improve until the late nineteenth and twentieth hundreds of years (Industrial Revolution - Wikipedia) The below figure shows that the ancient industry view,

Fig 20: Initial stage of industry (industrial revolution images - Bing images)

With this many advantageous aspects about industries we have so many disadvantages too, that is pollution.

With the happening to the Industrial Revolution, people had the option to progress further into the 21st century. Innovation grew quickly, science got progressed, and the manufacturing age materialized. With these came one more impact, modern contamination. Prior, businesses were little industrial facilities that created smoke as the essential poison.

Nonetheless, since the quantity of processing plants were restricted and worked just a specific number of hours daily, the degrees of contamination didn't develop fundamentally. Be that as it may, when these plants turned out to be full-scale ventures and manufacturing units, the issue of modern contamination began to take on more significance. (Howarde and Hesketh 1996).

The below figure shows that the present situation of industries.

Fig 21: Present Industries Picture (industrial present images - Bing images)

Any form of pollution that can trace its immediate source to industrial practices is known as industrial pollution. Most of the pollution on the planet can be traced back to industries of some kind. In fact, the issue of industrial pollution has taken on grave importance for agencies trying to fight against environmental degradation. Countries facing sudden and rapid growth of such industries are finding it to be a serious problem that has to be brought under control immediately. Industrial pollution takes on many faces. It contaminates several sources of drinking water, releases unwanted toxins into the air and reduces the

quality of soil all over the world. Major environmental disasters have been caused due to industrial mishaps, which have yet to be brought under control. Below are a few of the causes of industrial pollution that have resulted in environmental degradation. (Causes, Effects and Solutions to Industrial Pollution on Our Environment - Conserve Energy Future (conserve-energy-future.com).

The below figure shows the extreme pollution produced by the industries, as this study mainly concentrating on air pollution the same was depicted in the figure.

Fig 22: Pollution from Industries. (Pollution_From_Industries.jpg (640×427) (conserve-energy-future.com)

What Causes Industrial Pollution?

The causes of industrial pollution are not restricted to the emission of smoke or other harmful gases. There are many other reasons which leads to industrial pollution. Some of these causes are

1. Industrial growth without proper planning
2. Use of old technologies
3. Leaching of natural resources
4. A huge number of small-scale industries
5. Lack of policies for pollution control
6. Improper waste disposal
7. Emission of hazardous chemicals
8. Consumer products manufactured by industries.
9. Carbon emissions (Industrial Pollution - Causes, Effects and Prevention | Earth Reminder)

The main sources of air pollution is depicted in the below figure,

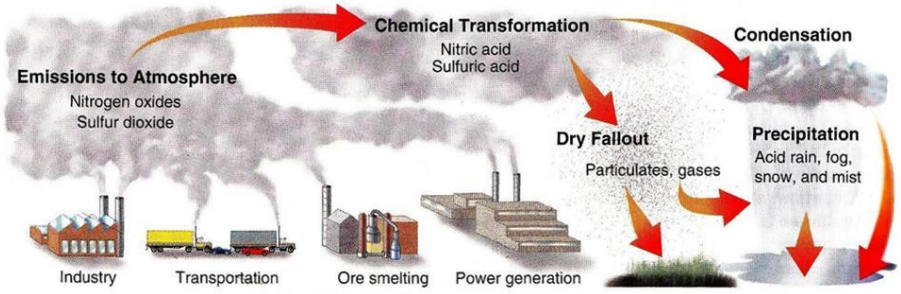

Fig 23: Various source of pollution (9743165_orig.jpg (970×333) (weebly.com))

Effects of Industrial Pollution

Industrial pollution is equally harmful to the environment as other pollutants like air, water, and land pollution. Actually, industrial pollution magnifies the level of air, water, and land pollutions in the environment. The harmful effects of industrial pollution include.

- **Causes air pollution**
  Industrial pollution mainly pollutes the air where we breathe. The industries emit a huge amount of harmful gases into the atmosphere daily. The process of emission will continue as these factories are running to fulfill our needs that are increasing rapidly every year.
  Due to air pollution, respiratory problems like bronchitis, emphysema, asthma, etc. are quite common in people these days. Apart from this, long term exposure to low-quality air also leads to lung infections, coughing, sore throat, wheezing, headache, chest pain, nausea, high-level fatigue, etc.
- **Contamination of water sources**
  Most of the factories required water to perform different activities to produce various products for consumers. When they use a large amount of water in various processes, it comes in contact with harmful chemicals, heavy metals, radioactive waste, etc.
- **Effects on the quality of soil**
  Industrial pollution is also affecting soil quality when the chemicals from factories get their way into landfills. As a result, the soil gets polluted, causing degradation of its quality. The low quality soil becomes a huge barrier in the agricultural field that affects the productivity of crops. Soil pollution also destroys local

vegetation. Soil pollution not only affects the vegetation but may also cause health issues to those people who come in contact with it on a daily basis.

- **Global Warming**
  Global warming is one of the biggest environmental issues that are making our planet hotter day by day. Multiple reasons are causing global warming, and industrial pollution is one of those. Smoke, CO2, and other greenhouse gases releasing from various industries are increasing the global temperature. Global warming is further associated with severe environmental problems like climate change, extreme weather events (such as flood, tsunami, drought, hurricanes, heat waves, etc.), melting of ice, sea-level rise, etc.
- **Effects on biodiversity of the planet**
  Industrial pollution is a big problem for humans undoubtedly, but it is actually affecting the entire biodiversity of the Earth. Sometimes *industrial accidents* also contribute to environmental pollution. For example – sudden fires, leakage of gases or radioactive materials, oil spills, etc.
  Plant and animal species are also affected by air pollution. The release of harmful toxins from industries is affecting the natural habits, reproduction system, and habitats of wildlife creatures. This is why many species of plants and animals have been extinct, and many others are endangered.
- **Leads to large packages for economic effects**
  Although industrialization refers to development and progress, we cannot deny its harmful effects on the environment. All countries have to raise big economic efforts to treat environmental degradation such as pollution control projects, campaigns for clean-up of water bodies, etc. Development is good for mankind, but all the aspects need to be looked after. Proper planning is crucial for industrial development and the sustainability of natural resources of the environment. (Industrial Pollution - Causes, Effects and Prevention | Earth Reminder)

Air pollution:

Before we look at air contamination from ventures, we need to comprehend the regular conditions and constituents of the environment. The climate, or air, is typically made out of around 79% nitrogen, 20% oxygen, and 1 percent combination of carbon dioxide, water fume, and little amounts of a few gases.

Main air Pollutants and Industrial Emissions Inventory

Significant Air Pollutants Air pollutants can be isolated into two fundamental gatherings—particulate and vaporous. The previous gathering incorporates strong airborne particulates like residue, fly debris, smoke, mist, ash, and vapor. Vaporous contaminations incorporate carbon monoxide, hydrocarbon, oxides of sulfur, and oxides of nitrogen. These poisons are known as essential air toxins. These materials may collaborate with each other within the sight of a fuel source to frame new auxiliary air pollutants like ozone and other extremely responsive materials. Auxiliary air contaminations additionally structure from responses with common synthetics in the air.

Table 10: Sources of Primary Air Pollutants

Pollutants	Sources
Carbon monoxide(CO)	Carbon monoxide(CO) Incomplete burning of fossil fuels Tobacco smoke
Hydrogen Carbon	Incomplete burning of fossil fuels Tobacco smoke, Chemical processes
Particulate	Burning fossil fuels, Construction operations Industrial waste
Oxide of sulfur (SOx)	Burning fossil fuels, Chemical processes Smelting ores
Oxide of nitrogen(NOx)	Burning fossil fuels, Oxide of N2 in atmosphere

Top three industries responsible for air pollution

There are various industries which contribute to air pollution in India. Some of the top polluting industries are discussed here.

Industrial chimney waste

There are various ventures which are wellspring of air contamination. One of them is petroleum refineries which emit gasses such as sulphur di-oxide (SO2) and Nitrogen oxide (NOx). In addition, cement factories also produce waste which are harmful to human health. Stone crushers and hot blend plants are additional source of pollutants. Furthermore, food and fertilizer industries which discharge toxic waste and corrosive vapors are also potentially harmful to the environment. (Heinsohn and Kabel 1999). Below fig shows the emission from the chimney.

Fig 24: Industrial Chimney Waste (industrial chimney waste - Bing images)

Thermal power stations

There are many power stations and super warm power stations in India. One of these is the National thermal power corporation (NTPC) which has set up four mammoth coal-fueled power stations located at Singrauli in U.P., Korba in M.P., Ramagundam in Andhra Pradesh and Farakka in W. Bengal. However, the main pollutants are fly powder, SO2 and different gasses and hydrocarbons.

Automobiles

Vehicular exhaust emissions are a source of extensive air contamination, next to warm power plants. Therefore, the steady expansion of the car industry increases air pollution risks, affecting air quality. The source of pollution in the auto industry the vehicle components such as:

- Framework
- Fuel tank and carburettor
- Crankcase

Furthermore, the fumes produce unburnt hydrocarbons, carbon dioxide (CO), Nitorgen oxide (NOx) and lead oxides. There are additionally hints of aldehydes, esters, ethers, peroxides and ketones which are artificially dynamic and consolidate to shape exhaust cloud in nearness of light. Similarly, evaporation from fuel tank due to the unstable nature of petrol, results in outflow of hydrocarbons. The evaporation through carburetor happens when motor is halted and warm air is emitted. During this process, as much as 12 to 40

ml of fuel is lost amid each long quit bringing on outflow of hydrocarbons. (Manufacturing industries as the major source of air pollution in India (projectguru.in) - By Indra Giri and Priya Chetty on June 17, 2017)Various effects of air pollution

- **On health**
  Air pollution is a complex mixture of different gaseous and particulate components and can cause several health effects. Both long- and short-term exposure to air pollution can cause cardiovascular diseases, respiratory diseases (e.g. asthma, chronic obstructive pulmonary disease) and mortality. Children are more susceptible to the effects of air pollution than adults. The lack of a fully developed pulmonary metabolic capacity in children make them more susceptible to air pollutants compared with adults [2]. Moreover, children are in general more exposed because of greater physical activity of children compared with adults, as well a greater time spent out of doors. (Bergstra *et al*., 2018).

- **On corporate cash holdings**
  To date, scholars have proven that the air environment can affect not only people's physical and mental health, but also seriously affect economic growth (Bin Li *et al.*, 2020)
  This paper examines the impact on air pollution of changes in the composition of manufacturing output in developed and developing countries. Pollution emissions from manufacturing output are estimated in a manner which holds constant the effect of technology and regulations allowing the impact of compositional changes alone on pollution to be estimated. The paper has three main findings; (1) the inverted-U estimated between per capita income and the pollution intensity of GDP arises due to both the composition of manufacturing becoming cleaner and the share of manufacturing output in GDP falling. Compositional changes alone are not responsible for the inverted-U between per capita income and per capita emissions: (2) changes to the composition of manufacturing output are consistent with the pollution haven hypothesis, however there is clear evidence that rising per capita incomes are associated with a falling income elasticity of demand for 'dirty' products. This fact may explain the compositional changes that occur with developments; (3) in addition to the income elasticity effect, the analysis suggests that land prices and to a lesser extent the prices of labor and capital, determine the proportion of dirty industry within a country's manufacturing sector. (Cole, 2000).

How Environmental Damage from Air Pollution is reduced

- Lower contamination levels mean less harm to the wellbeing of biological systems.
- Environmental effects of pollution include damage to plants and long-term forest health, soil nutrient deterioration, accumulation of toxics within the organic phenomenon, damage to fish and other aquatic nitrogen enrichment in coastal estuaries, which causes oxygen depletion and harm to fish and other aquatic animal species
- According to the peer-reviewed March 2011 EPA report, reducing emissions increases crop and timber yields, a boost worth an estimated $5.5 billion to those industries' welfare in 2010. In 2010, improved visibility conditions in selected national parks and metropolitan areas were reported to be worth $34 billion.

New force plants and industrial facilities utilize present day contamination control innovation. The Act requires that when new industrial facilities are designed and built, good pollution control must be a part of the planning. This proposes that as new, cleaner offices are fabricated, the country's modern base becomes cleaner overall In areas not meeting air quality standards, to avoid making pollution worse, new and modified large plants and factories must meet rock bottom achievable emission rate and acquire offsetting emissions reductions from other sources.

In areas that meet air quality standards, new and modified large plants and factories must apply the simplest available technology considering cost and avoid causing significant degradation of air quality or visibility impairment in national parks.

State and native permitting authorities usually administer the pre-construction permit programs that determine the way to apply these requirements to facilities. (Nath, 2021)

Pandemic: An Opportunity to Reduce Air Pollution

The pandemic of COVID-19 was more than a shock to the human immune system. It was also a shock to the Earth system, causing significant changes in air quality in cities all over the world. Countries around the world placed immediate shutdowns as they worked to control the epidemic. Scientists are now sifting through satellite and ground data to see what this pause in human activity might teach us about the atmospheric cocktail that causes pollution in cities. It was already understood that people's movements had been

curtailed to the point that greenhouse gas emissions and seismic noises had been drastically reduced. However, the quiet time did not last, and by the summer, carbon dioxide emissions had begun to rise again. This sudden halt in many human activities especially commuter traffic also provided scientists with an unparalleled opportunity to study the complex chemistry of urban pollutants. The shutdowns helped scientists better understand another longstanding affliction for human health: poor air quality in many cities, by altering the normal mix of pollutants lingering over cities. There is now a wealth of data from cities all over the world on how the pandemic affected regional or local concentrations of ozone precursors, a key component of smog. Nitrogen oxides and volatile organic compounds, both formed by traffic, as well as methane, produced by the oil and gas industry, are among the precursors. With satellites, scientists are able to monitor how pollutant levels have changed across the world. Although the shutdowns were more Strict in the spring, the researchers discovered that summertime nitrogen dioxide reductions were the most closely linked to the city's change in ozone levels. Since heat and sunlight react with precursor gases in the atmosphere, such as nitrogen dioxide, in the summer, a toxic cocktail is created. However, ozone levels in Denver were inconsistent, likely due to the fact that wildfires were raging across the United States by the end of the summer. The fires emit nitrogen oxides, carbon monoxide, and small particles, all of which contribute to the rise in ground-level ozone. There are different trends in different cities, and there are a lot of variables to consider and a lot of work to be done, according to a study.

Assessment of air pollution from small scale industry

Among small scale industries, the brick kiln industry is growing very fastly due to rapid urbanization and expansion of cities which created huge demands of building materials. Out of various building materials used in the country, clay bricks are most commonly used. In India, fire clay bricks are produced in about 42 000 small and medium scale brick kilns which operate normally using 4–5 mil metric tonnes of coal each year (NEERI, 1993).

Air pollution levels near kilns have assumed significant importance, as they do not only pose serious occupational health hazards but also aversively affect the surrounding environment (Aslam *et al.,* 1994). Therefore the study area is selected for the investigation where about 125 small and medium capacity bricks kilns were in operation. The estimated amount of coal consumed by brick kiln varies between 1.25 and 2 tons per day. Emissions from these industries vary with respect to quantity in relations to productions capacity, quality and quantity of fuel used. (Bhanarkar. *et al*., 2002). The

below Table show that the Stack emission characteristic of movable and fixed chimney in brick industries.

Table 11: Stack Emission Characteristic of Movable and Fixed Chimney

Parameters	Average	Movable	Fixed
Stack height	11.20 m	10 –12 m	32 –34 m
Stack diameter	0.51 m	0.4 –0.6 m	0.6 m
Exit gas velocity	4.80 m s^{-1}	3.38–5.71 m s^{-1}	0.4–0.55 m s^{-1}
Exit gas temperature	417°K	383 –513°K	323 –398°K
SPM emission rate	0.053 g s^{-1}	36 –223 mg m^{-3}	130 –167 mg m^{-3}
SO2 emission rate	0.248 g s^{-1}	152 –185 mg m^{-3}	135 –152 mg m^{-3}

Gas detectors in the process industries

Gas detection is an important safety system with interfaces to several other safety safeguards. However, the generality of the regulations, standards and recommended practices in conjunction with the inherent challenges of the gas detector placement problem, has resulted in a widespread use of prescriptive and qualitative detector placement strategies.

Gas detection is an important safety system with interfaces to several other safety safeguards. Incidents like the Buncefield fire are tangible and harsh reminders of the need for proper detection and mitigation. The Buncefield fire (Buncefield Major Incident Investigation Board, 2008).

Regulations, standards and recommended practices for gas detection systems mostly provide general guidelines regarding the placement of gas detectors. Recommendations and requirements are focused on installation, testing and performance, calibration, detection technologies and the type of actions expected in response to a confirmed gas leak. Most of them do not provide guidelines regarding the number of detectors or the placement strategies that should be used.

While effective technology exists for gas detection, several difficulties make the problem of gas detector placement in the process industry challenging. Leak location, size, and

duration are unknown, leading to a large uncertainty space and a large number of potential leak scenarios to consider. Second, formal quantification of the risk for any given leak scenario is difficult. The gas leak dispersion development and transport depend on fluid properties, environmental factors, and facility geometry. Reliable gas dispersion simulations are needed to accurately assess leak development. Finally, even if all this data is consolidated with the highest quality, due to the combinatorial aspects of the problem, exhaustive search is not an option. (Serrano *et al.*, 2014*).*

Scrubbers

The available methods for removing pollutants from a gas stream are numerous, to say the least. A popular method, scrubbers allow users to separate gases and solids by allowing the gas to come into contact with a liquid stream. In the end, the pollutants are washed away in the effluent, and the gas exits the system to be used in later processes or to be released into the atmosphere. For many years, counter-flow scrubber methods have been used for the lion`s share of the work in industries such as phosphate fertilizer and semiconductor chemicals manufacturing. Now these industries are exploring the use of cross-flow scrubber design, which offers consistently high efficiency and low operating costs. In addition, the unit`s horizontal orientation makes maintenance easier than typical tower scrubbers. For certain classes of unit operations, cross-flow is now being recognized as a strong alternative to conventional counter-flow technology. (Pedersen, and Bhattachararjee, 1997).

For more than a century, facilities in the chemical process industries have had to contend with a variety of regulated pollutants SOx, NOx, heavy metals and flyash in their flue-gases. Historically, operators of fossil-fuel-combustion processes have dealt with flue-gas pollution by operating a separate treatment facility for each pollutant. In recent years, however, an integrated, flue-gas-treatment system has emerged as a viable alternative to the traditional approach. By eliminating the use of an electrostatic precipitator in favor of several wet scrubbers and a downstream catalytic-reduction system for NOx, the new system shows operational and cost advantages over the conventional techniques. In this new method that uses three-stage flue-gas treatment, lime (calcium hydroxide, or Ca(OH){sub 2}) shows cost and operational advantages, and could displace limestone (calcium carbonate, or CaCO{sub 3}), the traditional favorite. For flue-gas treatment in the electric utility market, limestone currently dominates the scene. However, this may change as utility and industrial operators become more familiar with the potential advantages of using lime-based scrubbing solutions. (Rinaldi, 1995) Pollution demand and supply.We consider pollution emissions as the use of ‘environmental services’, an additional input in an industry’s production function. The equilibrium level of these

services reflects the interaction of an industry's demand for such services with the quantity which society is prepared to supply.

Pollution demand

There are a number of factors that may determine an industry's environmental demand schedule.

Energy use: Most air pollutants stem at least in part from the combustion of fossil fuels. The greater the use of fossil fuel in an industry's production process the greater the industry's demand for pollution.

Factor intensities: The pollution level of an industry may be influenced by its factor intensities.

Size: Other things being equal we would expect a positive relationship between a firm's total output and emissions, although we may expect this relationship to be diminishing at the margin. Thus, it is possible that pollution normalized by output might decline as output increases, reflecting the benefits of economies of scale in both resource use and in pollution abatement.

Efficiency: Emissions are likely to be a negative function of efficiency. One would expect a more productive industry to be better managed, more resource efficient and to produce less waste per unit of output. Furthermore, such an industry would also be better placed to respond relatively quickly to any change in pollution control incentives.

Use of modern production processes: We would generally expect a newer plant or one that uses modern production processes to be cleaner. As environmental regulations have become increasingly stringent, modern production processes have become more resource efficient and hence produce less waste per unit of output.

Innovation: It is hypothesized that the level of innovation displayed by a firm or industry may reduce its demand for pollution. Firms undertake research and development (R&D) with a view to achieving either product or process innovations. The benefit of the latter is the attainment of greater efficiency, i.e. fewer inputs per unit of output. Process innovations may also provide ways of recycling waste products so that waste is reduced and fewer raw materials are required as inputs. A firm or industry undertaking a significant amount of such investment may be expected therefore to be less resource intensive, and hence cleaner.

Pollution supply

Environmental regulations: Environmental regulations will ensure that the greater the use of environmental services (i.e. the larger the emission of pollution) the higher the costs imposed on any firm or industry. The result is an upward sloping 'environmental supply schedule'.(Cole, et al., 2004).

Air quality in Indian cities

The national ambient monitoring program collects 24-h averages of key air pollutants 2e3 times per week at 342 manual stations in 127 cities. This program is managed by CPCB. However, only a limited number of cities operate continuous monitoring stations, measuring the full array of criteria pollutants and access to the monitoring data is limited.

The number of studies in various cities is presented in Table 2, with limited number of studies on PM2.5 size fraction. (Sarath, et al., 2014).

Industrial Emissions Inventory

Because of the wide assortment of modern cycles, solid conclusions of industrial outflows have been found to rely upon singular kinds of treatment. This is costly and tedious, as it includes point by point study and testing of explicit plants and cycles. At times, information on mechanical outflows could be acquired through surveys shipped off the individual plants mentioning data on cycles, types and amounts of interaction exhaust, air cleaning gear and fuel utilization. Habitually, the actual businesses don't have on-line information of this sort. Therefore, deficient or inadequate outcomes can be anticipated. Data on air outflows can likewise be acquired by utilizing designing evaluations which depend on the crude materials or fuel devoured in a given cycle and detailed figures on types and pace of poisons discharged per unit weight of crude material or fuel utilized in a specific interaction. Sadly, there doesn't exist an adequate group of promptly accessible and solid data on measure emanations got from real tests, so it is hard to acquire palatable outcomes. The itemized strategy for making a mechanical study includes the utilization of a PC card distinguishing every foundation and its area. A point by point survey shipped off every foundation to gather data, which remembers information for plant size, working timetable, fuel utilization, cycles, and dissolvable use. This method may give more dependable outcomes. Discharge factors, which have been applied to source information to yield emanation information for SOx, NOx, HC, CO, particulates, etc. exist for a wide assortment of mechanical cycles, for example, fuel copying, synthetic creation, fabricating cycles, and dissolvable utilization. (HAO and LI)

Table 12: Number of Receptor Modeling Studies Conducted between 2000 and 2013 in India.

City	PM10	PM2.5	PM1	PM10 & PM2.5	Mixed fractions	Total
Delhi	4	1		1	5	11
Mumbai	3	1		1	2	7
Kolkata	2	1			1	4
Chennai	1	1		2		4
Hyderabad		1		1		2
Agra				1	1	2
Kanpur			1			1
Ahmedabad				1		1
Chandigarh					1	1
Tirupati	1					1
Talcher	1					1
Dhanbad	1					1
Jorhat		1				1
Virudhanagar				1		1
Mithapur					1	1
Bhubaneshwar					1	1
Multi-city		1		1		2
Raipur	1				5	6

Policy implications on air pollution

National Clean Air Program

A long-term, time-bound, national-level strategy to tackle the increasing air pollution problem across the country in a comprehensive manner. The total tentative cost of NCAP is estimated at Rs 637 crore.

Objective: Comprehensive management plan for prevention, control and abatement of air pollution, besides augmenting the air quality monitoring network across the country.

Focuses on: Collaborative and participatory approach covering all sources of pollution and coordination between relevant central ministries, state governments, local bodies and other stakeholders

- Intensive awareness, training and capacity-building drive, with specific impetus on augmentation of manpower and infrastructure facilities of the Central Pollution Control Board (CPCB) and the state pollution control board (SPCBs)
- A credible, transparent and accountable data collection and monitoring system that is available for timely swift action is to be ensured
- Increasing the number of monitoring stations, data dissemination, public participation on planning and implementation
- Setting up of air information centre for data analysis, resource apportionment studies, national inventory and rural monitoring stations, besides guidelines for indoor air pollution

Recently, The National Green Tribunal (NGT) has directed the Ministry of Environment, Forest and Climate Change (MoEFCC) to modify the National Clean Air Programme (NCAP)

According to the 2011 census, 2774 rural settlements are now reclassified as urban settlements, pushing the total to 3894, primarily based on the definition of an urban settlement e population exceeds 5000, population density is above 400 per km2, and more than 75% of the male workforce is employed outside of agriculture (Census-India, 2012). The population in urban areas is expected to grow from 30% to 50% by 2030 (MoUD, 2011).

By 2030, the expected growth in industrial, transportation, domestic, and power generation sectors will consequently result in an increase in emissions and air pollution for almost all the cities listed and many more cities which are medium and small today.

There are growing concerns about the impact of air pollution on human health and general well-being, which requires a multi-pronged approach for better air quality. Some key institutional measures which can lead the way are the following.

The first Industrial Policy for Delhi was introduced in 1982. Subsequently, a second Industrial policy (2010–2021) was issued by the Department of Industries, Government of Delhi.

It is a comprehensive document envisioning higher industrial development in Delhi, with one of its mandates being to develop clean and nonpolluting industries and details of steps to be undertaken in this direction have been described.

Benefits Accrued as a Result of Control Measures

1. Since the first act on pollution was instituted, huge progress has been made in terms of human resource, infrastructure development and research capability. Some studies tried to gather evidence for the effectiveness of control measures by comparing pre- and post-intervention health status. The study conducted by the Central Pollution Control Board demonstrated that spending 8-10 h in clean indoor environment can reduce health effects of exposure to chronic air pollution.

2. A recent study found significant improvement in the respiratory health following large-scale government initiatives to control air pollution. It was reported that use of lower-emission motor vehicles resulted in a significant gain in disability-adjusted life-years in Delhi. Another study found significant evidence for reduction in respiratory illness following introduction of control measures. (Rizwan *et al.*, 2013)

Policy implementation in other countries

How the Air Pollution Prevention and Control Action Plan Is Assessed.

There are two assessment aspects for the evaluation of the Action Plan. The first one is the actual improvement of the air quality, quantified as the reduction in particulate matter (PM) concentrations.

The second one is the accomplishment of key tasks for air pollution prevention and control, and these tasks include industrial restructuring, clean energy generation, coal and oil quality management, small coal-fired boiler control, industrial emissions (dust and Volatile Organic Compounds-VOCs), municipal dust control, vehicle pollution control, air pollution control investment, building energy-saving and heat metering management, and atmospheric environment management.

The two aspects were evaluated separately for BTH, PRD and YRD, and the lower score of these two aspects was the final score. The time frame for the Action Plan is from 2012 to 2017. More detailed information on performance assessment measures of the Action Plan can be found.

At the end of 2012 and the beginning of 2013, heavy smog covering the BTH region arose public concern about air pollution. Immediately after the incident, the government launched a series of air quality control strategies including guidelines, laws and other

measures. Among these strategies, the Air Pollution Prevention and Control Action Plan, which included specific measures and assessment methods, acted as the guideline for air pollution control measures. The air pollution reduction targets at provincial or municipal level can be found.

Industrial Emission Control Since the preparation for the Olympic Games, the central government has engaged in relocating heavy industries from Beijing to its surroundings, mainly to Hebei. Faced with high energy consumption, high pollution emission, and exacerbating environmental degradation, in 2013, the central government launched a national call to decrease the production capacity and to transform and upgrade the equipment and production processes in Hebei and other provinces. The concern about public health impacts of high air pollution has accelerated industry restructuring in the BTH region. Figure 2 indicates the industrial restructuring enforcement procedure in Hebei Province. (Wang *et al.*, 2018).

Environmental Monitoring

Environmental monitoring is a tool to assess environmental conditions and trends, support policy development and its implementation, and develop information for reporting to national policymakers, international forums and the public.
The main objective of environmental monitoring is to manage and minimize the impact an organization's activities have on an environment, either to ensure compliance with laws and regulations or to mitigate risks of harmful effects on the natural environment and protect the health of human beings.

Air Monitoring

Air pollutants are known for their adverse effects on human health and ecosystems. Some of these pollutants also erode technical infrastructure and cultural monuments. Emissions of nitrogen oxides and non-methane volatile organic compounds are the main causes of the formation of ground level ozone, which has adverse effects on human health and ecosystems. The air pollutants indicator assesses pressures from specific pollutants on atmospheric air across individual countries, but also identifies pressures from particular national sectors like energy, transport, industrial processes, agriculture and waste management.

On the basis of this indicator, public authorities can adjust the national environmental policy by, for instance, revising emission standards and emission limit values, strengthening permitting of potentially polluting activities and improving the application of economic instruments. Information on pollutant emissions is necessary for the assessment of trans boundary air pollution and for international cooperation to address this problem.

Water Monitoring

Renewable freshwater resources have major environmental and economic value. Their distribution varies widely among and within countries. Pressures on freshwater resources are exerted by overexploitation and by pollution. Relating resources abstraction to renewal of stocks is a central issue in sustainable freshwater resource management.

The convention on the protection and use of Trans boundary Watercourses and International Lakes requires that the parties introduce sustainable waste management, including an ecosystem approach and the sustainable freshwater resource management, including an ecosystem approach and the rational and fair use of trans boundary waters. (Adler et Al., 1993)

Biodiversity

Sustainable development depends on a sound environment, which in turn depends on ecosystem diversity, protected areas, especially the full range of International Union for Conservation of Nature (IUCN) protected area Categories, are essential for conserving biodiversity and contributing to sustainable development.

The biodiversity indicator provides a means to measure the response to the degradation of ecosystems and the loss of biodiversity in a country. It demonstrates the extent to which areas important for conserving biodiversity, cultural heritage, scientific research, recreation, natural resource maintenance and other environmental values are protected from incompatible uses.

Waste Monitoring

Waste represents a considerable loss of resources in the form of materials and energy. The treatment and disposal of waste may cause environmental pollution. And expose humans to harmful substances and infectious organisms. Waste generation is closely linked to the level of economic activity in a country, and reflects the society's production and consumption patterns.

The main purpose of the waste indicator is to measure the pressure on the environment of the total amount of generated waste and waste by category. The waste intensity represents a driving force indicator and shows response to anthropogenic activities. (Ivan Secerov et Al., 2018).

Benefits of Environmental Monitoring

Purpose and benefits of Environmental Monitoring is to understand whether the quality of environment is getting better or worse. Information collected by Environmental Consultants by Monitoring Environment is very helpful to take decisions for government and non-governmental bodies. The most important purpose or benefit of Environmental monitoring is to see and analyze trends & patterns of the presence of air pollutants in the atmosphere.

The purpose or objective of environmental monitoring is different in different situations, but important aims to environmental monitoring are ensuring company's compliance with environmental regulations, evaluating the efficiency of the newly installed machine, evaluating the health of employees. It helps to find risks to human and wildlife, scope to population migration from high-density areas to low density areas and also to restrict emission of gases.

Benefits of Environmental Monitoring information for Non-Governmental Bodies
Many companies, people, and organizations use data of environmental monitoring to cope with the environment and to reduce the pollution to make life better.

Below is the list of points of Importance of environmental monitoring:

Healthcare Professionals

Healthcare professionals are the ones who help to treat and create more awareness about the disease and ways it can be controlled. They are also concerned about the environmental impact of a particular project, eg. High noise levels, low ambient air quality etc.. They are also concerned about the effects of pollution on environmental and human health for the long term as well as short term.

Architectures and Engineers

Objectives of Environmental Monitoring, when engineers plan for the new highway on the sea. They should know what is a high level of sea water could rise, what is vibration level at the bottom of the sea or what are the other environmental factors which may affect the strength of the bridge. So that they can take precautionary measure while constructing a bridge.

Emergency Responders

When tsunami, earthquake occurs in a particular area it is very important to spread accurate information like co-ordinates of location, time and severity level, so that they can deliver help to specified time and place without any delay. Also, the Benefits of Environmental Monitoring are to predict and respond to such events.

Resource Management

Farmers, Foresters, hunters and Fishers can plan their work based on weather i.e. Environmental Monitoring data Such as heavy rainfall, cyclones and tsunami. If they are informed before considerable time then the severity of the natural hazard can be lowered. Also, farmers can know about their fertility of the soil so that they can use required fertilizers to improve yield.

Industries

Major Industries need to know about what type of pollutants and in what quantity are emitted from their premises. They should be in national standards, but for that, they need environmental monitoring data to take actions to reduce environmental pollution.

Different types of Environmental Monitoring

Benefits of Environmental Monitoring information for Governmental Bodies.
Importance of environmental monitoring is not just to provide information to Industries but also Government bodies. Below are some objectives of environmental monitoring for Governmental bodies. (Bethesda, 2004)

Environmental Management Programs

The Environmental Management program is actions of plans that are necessary to achieve environmental targets and objectives and it cannot be achieved without environmental monitoring. A successful environmental management program can be started assessing current environmental health before starting.

Allocation of Population

With the help of population monitoring, data government can decide for population. Management. If a particular city is having a high density of population and they are facing problems in water supply, electricity and most importantly space/land, then the government can decide to move some of the industrial areas to low-density areas. Also, the government creates new cities like New Delhi, New Mumbai etc. by taking advantages of environmental monitoring data.

Compliance Evaluation and Environmental regulation

Based on environmental monitoring data they can decide to evaluate the performance of concerning regulations. If for eg. From 2001 to 2010 Air pollution has increased considerable then the government can decide to restrict limits for that particular location or the national level.

Regulatory Approach

Benefits of Environmental Monitoring data are that gives an idea about if the regulations and enforcement are working as anticipated. If all regulations are followed but the quality of the environment is not increasing then the government can take action to change the regulatory approach.

Helping Scientific Research

Environmental monitoring is closely related to scientific research. E.g. If environmental Monitoring programme a particular pollutant which can harm wildlife or aquatic life, then the government can take action. Also, it can trigger research on effects of that pollutant on human, wildlife or aquatic life so that they can create treatment procedures.

Environmental Monitoring includes Monitoring of air, Water, Soil and lands, plants and animals, ecosystems, Human population. Also it helps to identify environmental stress, understand environmental patterns and evaluate the effectiveness of strategies and programs. (Committee on Environment and Natural Resources)

Industrial Environmental Monitoring

An environmental monitoring system is used to analyze air, water, and soil samples and monitor the quality of the environment. This system controls and monitors the environmental state during and after an industrial operation.

Leading companies are engaged in inventing advanced technologies and developing industrial environmental monitoring systems to monitor and control the harmful effects of industrial operations. Increasing awareness about environmental pollution control is considered to be one of the major factors affecting the growth of the industrial environmental monitoring system market.

Supportive government rules and regulations to reduce environmental pollution along with increased government funding to prevent and control environmental pollution are expected to boost the growth of the industrial environmental monitoring system market.

Moreover, an ever growing oil & gas industry coupled with development of high-end environmental monitoring systems based on nanotechnology are expected to create ample growth opportunities in the market in the upcoming years.

However, high cost associated with environmental monitoring solutions is expected to be a major factor limiting the growth of the industrial environmental monitoring system market in the upcoming years. In addition, slow adoption of pollution control policies in emerging economies is anticipated to hinder the industrial environmental monitoring system market growth.

Global Environmental Monitoring System

Since it was introduced in 1975 at the United Nations Conference on the Human Environment, the Global Environment Monitoring System (GEMS) is a global operation that collects information to better understand and protect the Earth's environment. This effort is made with the cooperation of other countries, who contribute data to the GEMS.

One of the many projects that the GEMS has been studying has been water quality. Since 1978, the GEMS has examined the quality of surface and ground water to find trends that will shape water quality policy. With the cooperation of environment research programs from member nations all over the world such as the National Water Research Institute in

Canada, GEMS can provide information of resources like water to ensure resources are used sustainably. (http://www.unep.org/gemswater).

Scientists need monitoring as part of integrated environmental research programs. Policy makers need monitoring to design, implement, and evaluate effective environmental policies. The public needs monitoring to track our nation's natural resources. Monitoring is an essential component of environmental science and deserves the careful attention of scientists and greater support from government agencies and other funding sources.

Utilization of Eco Friendly Technologies

Sustainable technology is an umbrella term that describes innovation that considers natural resources and fosters economic and social development. The goal of these technologies is to drastically reduce environmental and ecological risks and to create a sustainable product. Sustainable technology aims to minimize any negative social and environmental impacts, which is good for a business's bottom line, and its reputation.

Sustainability in technology can be defined in a few ways:

- **Substitution.** The technology fosters a shift from non-biodegradable to biodegradable materials in its production. It also replaces non-renewable with renewable resources.
- **Prevention.** The sustainable technology prevents deterioration, contamination, and other negative environmental impacts through its use or production.
- **Efficiency.** The technology is efficient in terms of its use of energy and resources.

Examples of Sustainable Technology

Sustainability in technology has already made its way into public use and innovation. Common examples of sustainable technology and innovations include:

1. Public and electric transport
2. Zero flush in urinals
3. CFBC Boilers
4. BLDC Motor
5. Heat transfer pumps
6. LED lights

1. PUBLIC AND ELECTRIC TRANSPORT:

Sustainable transport refers to the broad subject of transport that is sustainable in the senses of social, environmental and climate impacts. Components for evaluating sustainability include the particular vehicles used for road, water or air transport; the source of energy; and the infrastructure used to accommodate the transport (roads, railways, airways, waterways, canals and terminals). Transport operations and logistics as well as transit-oriented development are also involved in evaluation. Transportation sustainability is largely being measured by transportation system effectiveness and efficiency as well as the environmental and climate impacts of the system. Transport systems have significant impacts on the environment, accounting for between 20% and 25% of world energy consumption and carbon dioxide emissions. The majority of the emissions, almost 97%, came from direct burning of fossil fuels. Greenhouse gas emissions from transport are increasing at a faster rate than any other energy using sector. Road transport is also a major contributor to local air pollution and smog. An electric vehicle (EV) is a vehicle that uses one or more electric motors for propulsion. It can be powered by a collector system, with electricity from extravehicular sources, or it can be

powered autonomously by a battery (sometimes charged by solar panels, or by converting fuel to electricity using fuel cells or a generator). EVs include, but are not limited to, road and rail vehicles, surface and underwater vessels, electric aircraft and electric spacecraft.

EVs first came into existence in the mid-19th century, when electricity was among the preferred methods for motor vehicle propulsion, providing a level of comfort and ease of operation that could not be achieved by the gasoline cars of the time. Internal combustion engines were the dominant propulsion method for cars and trucks for about 100 years, but electric power remained commonplace in other vehicle types, such as trains and smaller vehicles of all types.

Sustainable transport systems make a positive contribution to the environmental, social and economic sustainability of the communities they serve. Transport systems exist to provide social and economic connections, and people quickly take up the opportunities offered by increased mobility, with poor households benefiting greatly from low carbon transport options. The advantages of increased mobility need to be weighed against the environmental, social and economic costs that transport systems pose. Short-term activity often promotes incremental improvement in fuel efficiency and vehicle emissions controls while long-term goals include migrating transportation from fossil-based energy to other alternatives such as renewable energy and use of other renewable resources. The entire life cycle of transport systems is subject to sustainability measurement and optimization.

2. ZERO FLUSH IN URINALS:

Billions of gallons of water are used annually to flush toilets in the United States. Consequences of this usage include consumption of natural resources and construction of new infrastructure to treat and transmit potable water and wastewater. Waterless, or no-flush urinals, may help mitigate these effects and offer other advantages, including lower utility charges, improved restroom hygiene, and decreased fixture maintenance. Some notable caveats include possible lack of acceptance by users, odor control problems, and rejection by code officials. As urine is about 96% liquid, no additional water is really needed to wash it down the drain. The waterless, urinal, looking much like its conventional counterpart, takes advantage of this concept with generally positive result.

DESIGN AND OPERATION

The waterless urinal appears and works like a conventional urinal, except that it does not flush and, therefore, requires no water. Like their traditional counterparts, waterless urinals are made of fiberglass or vitreous china, and are offered in white as well as various custom colors ADA compliant models are also available. No-flush urinals can be installed virtually anywhere the conventional variety would be used. Like ordinary urinals, waterless types are plumbed to a standard drain line, but obviously do not use a conventional water-filled trap. Waterless urinals utilize proprietary sealant liquids that act

as a vapor trap. The liquids are composed primarily of natural oils that are lighter than water. Urine passes through this liquid and goes down the drain. The sealant liquid, except a minuscule amount that escapes with each use, remains in place to trap odors and prevent them from escaping into the restroom. The various manufacturers of waterless urinals available in the U.S. use three types of drain trap designs. Two companies utilize a removable, recyclable plastic cartridge that is inserted into the fixture's drain hole. although they vary somewhat by manufacturer. Another maker employs an integral ceramic siphon that is cast into the urinal, and the last utilizes a built-in waste trap housed in the fixture drain. In all cases, whether removable or not, the drain trap is designed to contain the sealant liquid. The removable cartridge, according to manufacturers' literature, serves two other purposes in addition to holding the sealant liquid. First, it acts as a strainer to keep unwanted materials such as chewing gum and cigarette butts out of the drain. Also, it captures sediment from urine that would otherwise go down the drain and potentially create obstructions. Models with integral siphons do not have a strainer, so their manufacturer recommends flushing the drain line with water on a monthly basis. The built-in trap version has a drain cover that should catch larger items before they go down the drain. For models with drain inserts or cartridges, the cover is twist-locked in place. A special tool supplied by the manufacturer is required to remove it, thus reducing the chance of unwanted removal and opportunities for vandalism.

APPLICATIONS

No-flush urinals can be installed at virtually any location that conventional flush type urinals would go. Installation locations have included airports, schools, colleges and universities, offices, hospitals, stadiums, convention centers, parks, and rest areas.

Waterless urinals are suitable for both new construction and retrofits. In both applications these urinals are installed essentially like conventional ones, except that no water hookup is needed. However, some owners prefer to install water supply lines to the urinals' location and cap them in case they are not satisfied with the waterless urinals in the future. Some building officials are reportedly requiring this type installation as a condition of approval as well. Waterless urinals fit to standard 2- inch drain lines, but not copper. The urea in urine can react with copper to cause pitting and corrosion.

For retrofits the height of existing drain piping may need to be modified to allow mounting of the new waterless urinals at the proper heights. This adjustment is due to the fact that drain outlets on conventional and water free urinals are often at different locations relative to the fixture bottom. Also, one source recommends ensuring existing drain lines are clear of obstructions, snaking them if necessary, prior to installation. This removes any existing encrustations in the lines, which, according to no-flush urinal manufacturers, accumulate due to reactions between urine and water.

While they can be used almost anywhere, waterless urinals are a practical option where facilities are not connected to a sanitary sewer system. Since there is no flushing, septic

systems or on-site treatment facilities do not fill with water from urinals. No-flush urinals may also be attractive in locations such as parks and rest areas where heating is not provided in the winter, since freeze protection is not required.

Advantages:

Water Savings:

Toilets account for about half of a typical building's water consumption. In the United States, almost 5 billion gallons of water is used every day to flush toilets, according to the Environmental Protection Agency. Newer models of conventional flush-type urinals use about one gallon per flush. Older ones can use from three to five gallons. Since no-flush urinals use no water, one to five gallons of water is saved with each use.

Low Maintenance:

Waterless urinals generally require little maintenance other than a few simple procedures that are outlined below (see Maintenance). The absence of a flush valve eliminates valve repairs and reduces opportunities for tampering. Additionally, overflow due to clogged drains and vandalism is not a problem since large amounts of water are not being flushed. According to the manufacturers, drain lines on waterless urinals are less susceptible to clogging as the mixture of water and urine, absent with no-flush urinals, causes encrustations to form in the pipes. Occasional flushing with a few gallons of water is recommended to keep lines clean.

Improved Hygiene:

Many people have the impression that urine is an unclean substance. However, it is generally a sanitary composed mainly of dissolved metabolic waste and excess water. A person's urine normally does not contain harmful microorganisms unless they are harboring some type of urinary tract infection. Water used by conventional urinals gives germs in the restroom the moist environment they need to grow. Manufacturers design waterless urinals to dry out between uses. This makes them hostile to bacteria and viruses. Also, since there is no handle, no-flush urinals are touch-free, reducing the spread of communicable diseases.

Odor Control:

The absence of a water-urine blend in the bowl lessens the prevalence of odors often associated with urinals, according to at least one manufacturer. The sealant liquid filling the trap is designed to keep odors out of the restroom. However, some owners report that odors might become noticeable if the supply of sealant liquid is allowed to run out.

Environmentally Friendly:

Waterless urinals contribute positively to the environment. First, the absence of water for flushing reduces the demand for water, an increasingly scarce commodity in some areas. Also, since no water goes down the drain, additional wastewater requiring treatment is not generated. Next, the special drain cartridges and inserts used in some models are recyclable. Finally, the sealant liquid composed of natural oils is biodegradable.

Rebates and Incentives:

Some water utility companies offer rebates and incentive payments to owners installing waterless urinals. Payments range from a partial to full reimbursement for the cost of no-flush urinals. In Texas cities participating in these type programs are generally in the central and western parts of the state such as Austin and El Paso. Some areas in the west, including many in the Seattle, Washington, region also offer incentives for no-flush urinal installation.

Energy Reduction:

Widespread use of waterless urinals could result in an overall reduction in the use of energy. Cities and other water supply agencies would not have to treat and pump as much water.

"Green Building" Credits:

Many new construction projects nowadays are earning certification as "green buildings" under the LEED program developed by the U.S. Green Building Council. Installation of waterless urinals helps gain water conservation points.

3. CFBC BOILERS:

Circulating fluidized bed combustion (CFBC) power generation technology has developed rapidly in the last 30 years, and is now fully commercial and available at sizes up to 600 MW. However, pulverized coal (PC) boiler technology remains the primary power generation technology for premium fuels and CFBC technology is used mainly to fire fuels not suited for PC applications. The chapter shows that up to 500 MW capacity CFBC plants hold a thermal and economic advantage over PC plants even when fired with premium fuels, and that this advantage is enhanced by their ability to fire low-cost 'opportunity' fuels. To maintain their cost competitiveness, CFBC plants need to progress to the larger sizes at which PC plants are available, 750 MW and above.

CFBC technology has a number of advantages over BFBC technology, including (Wu, 2003) the following:

- Improved combustion efficiency and sulfur retention due to the use of finer particles, turbulent gas-particle mixing, and a high recycle rate

- Smaller bed area due to the use of high fluidizing velocities
- Reduced number of fuel feed points due to the smaller combustor size and turbulent mixing
- Reduced erosion and corrosion of heat transfer tubes because tubes immersed in the fluidized-bed cooler are subjected to significantly lower gas and particle velocities than in a BFBC and the cooler is subjected to oxidizing conditions, whereas reducing conditions occur near the fuel feed points in the BFBC
- Increased convective heat transfer coefficients

4. BLDC MOTOR:

A Brushless DC Electric Motor (BLDC) is an electric motor powered by a direct current voltage supply and commutated electronically instead of by brushes like in conventional DC motors. BLDC motors are more popular than the conventional DC motors nowadays, but the development of these type of motors has only been possible since the 1960s when semiconductor electronic.

Advantages of Brushless DC motor:

Brushless DC motors have many advantages our the traditional brushed DC motors. Few of the advantages are discussed below in detail:

- Brushless DC motor does not have any carbon brushes, which reduces frequent replacement requirements of brushes and maintenance costs.

- Brushless DC motors have better performance and efficiency as compared to the brushed DC motors due to the involvement of electronic control enabling high-level control over the speed and position of the motor. Brushless DC motor lifespan is approximately 6 times higher than the counter brushed DC motor.

- Brushes can cause high sparks which may result in short life or complete burnout of brushed DC motor. However, in the case of brushless DC motor, due to no spark issue, there are fewer chances of burnout due to sparking issues.

- Brushless DC motors are available in small compact sizes and also provide high torque to weight ratio making it suitable for many robotics and medical applications involving robotic arms and robotic legs.

- Brushless DC motor produces comparatively low operating noise as compared to other motors of the same ratings. As in other motors, there is continuous contact

of brushes resulting in noise and sparking during contact. Therefore, brushless DC motors are given preference where electrical noise needs to be avoided.

- As traditional commutation based on mechanical setup is replaced by the modern electronic commutation system resulting in more control and fewer chances of failure due to previously discussed reasons of wear and tear.
- Unlike other motors, brushless DC motor has low no-load current making it suitable to run it at low or no load.
- Brushless DC motors can provide maximum torque continuously during rotation, while brushed DC motor can provide maximum torque at an only specific point of the rotation. For the same torque rating, the brushed motor will require a much bigger magnet as compared to the brushless DC motor. This results in a very compact and small-sized brushless DC motor proving very high torque rating.
- Brushless DC motors can have a feedback control to monitor and control the speed and torque, resulting in accurate torque and speed control providing higher efficiency, low power consumption, and long battery life in the case where the motor is operating using some batteries.
- Brushed DC motors have the heating issue and do not cool quickly due to the presence of electromagnet in the center of the motor. On the other hand, the brushless DC motor does not have an electromagnet in the center reducing the heating issue.

5. HEAT TRANSFER PUMPS:

Heat transfer fluid (HTF) pumps circulate thermal oil through the parabolic troughs to heat it up and pump it to the solar steam generator. The main characteristics of the HTF pumps are their high temperature and their double sealing system. Depending on the plant size, HTF pumps can be either double or end suction type.

In many industrial processes, heating and cooling play essential roles in the implementation or achievement of special quality characteristics. More specifically, processes in which heat transfer fluids supply or remove energy serve this purpose.

The ideal heat transfer medium is water. Unfortunately, the vapor pressure of water rises sharply with increasing temperature, so water-based systems must be designed for high pressures. This makes them expensive. Alternatively, mineral oil-based and synthetic heat transfer fluids as well as silicone oils have been developed that allow operation at high temperatures under moderate pressure.

Mineral oils can be used for temperatures up to about 570°F (299°C); they have dominated the market for decades. Application temperatures up to 750°F (399°C) can be covered with synthetic heat transfer fluids. For a long time, 750°F marked the feasibility limit for heat transfer systems.

Technical progress demands higher temperatures, however. Silicone oils now offer the possibility of significantly exceeding the 750°F limit.

The use of ground source heat pump (GSHP) systems (also referred to as shallow geothermal or geo-exchange) is increasingly being considered as an energy efficiency measure to service varied heating and cooling loads. Such systems have the potential to provide carbon emission reduction and cost savings relative to traditional heating and cooling plant, due to their superior energy efficiency. A GSHP system comprises three key elements:

1. The thermal load: the building or process heating and/or cooling demand that results in a serviceable thermal load.

2. The heat transfer system: the plant; comprising heat pumps, heat exchangers and associated controls.

3. The thermal sink and/or source: the receiving environment coupled to the heat transfer system via a ground collector (typically a horizontal loop, abstraction and recharge bores or borehole heat exchangers (BHE)).

While the underpinning technology is not new, best practice in design is still evolving. One challenge in GSHP projects that requires attention is sustainability, for which clear targets do not currently exist. While sustainability must address short and long-term considerations for the water resources of the area, a true assessment of sustainability requires the wider system beyond hydrogeological elements to be assessed.

To determine if a GSHP system can be considered sustainable, a series of tests are proposed:

1. Can the peak thermal loads be serviced by the receiving environment within the boundaries of the site.

2. Will there be an unacceptable change in the receiving environment or to any thermally sensitive receptors due to the long-term operation of the system

3. Will the system operate in the long-term as intended, to maintain economic and environmental feasibility for the design life of the system.

In particular, temperature change resulting from GSHP system operation (referred to herein as thermal interference) and water quality impacts, require specialist assessment. While these tests may appear obvious to an accredited or experienced GSHP designer,

they may be less obvious to others, including traditional HVAC designers and installers, or hydrogeologists who are not familiar with GSHP technology. A suitable framework for assessing sustainability should be capable of meeting the needs of GSHP designers, the wider HVAC project team as well as the regulators.

6. LED LIGHTS:

LEDs are well-known for their efficiency, which translates to energy savings for the consumer energy savings for the consumer. But they have many other characteristics that make them the best choice from a sustainability perspective too.

Sustainable Characteristics of LEDs

LED lighting supports sustainability in several different ways:

1. Low energy consumption. LEDs use less energy than other types of light bulbs. This saves the consumer money and places less demand on our energy grid and, ultimately, less demand on the natural resources used to power that grid.

2. Low heat. Much of the energy consumed by other types of light bulbs is wasted as heat loss. LEDs don't have this same amount of heat loss, thanks to their efficient design and lack of filament. Cooler bulbs are safer too, posing less of a fire hazard.

3. No harmful materials used in construction. LED lights do not contain any harmful chemicals or materials. Unlike CFL bulbs, which contain mercury and require special precautions to dispose of them properly.

4. Waste reduction. Since LEDs last so long (up to 20 years or more) and are more durable than other types of bulbs, fewer dead LED bulbs find their way into the trash.

5. Recyclability. LEDs are made of recyclable materials. Although you can't throw them out with the curbside recyclables, LEDs can be taken to special collection events or drop-off locations where they can be collected and sent off to be dismantled. Parts can then be reused, repurposed, or recycled.

One important, but intangible, way LEDs support sustainability is in their influence on building practices and lifestyles. We have many choices when it comes to designing, constructing, or retrofitting buildings today. LEDs are consistently at the top of the list of "green", "sustainable", and "energy-efficient" building options. Even

> if LEDs aren't everyone's choice in lighting, the fact that they can even get the conversation going about sustainable options, is a step in the right direction.

Moving towards a green economy has the potential to achieve sustainable development and eradicate poverty on an unprecedented scale, with speed and effectiveness. This potential derives from two concurrent changes. First, there is a changed playing field in which our world and the risks we face have materially changed. These changes require a fundamental rethinking of our approach to the economy. Second, there is a growing recognition that the natural environment forms the basis of our physical assets and must be managed as a source of growth, prosperity and well-being.

Setting up of Environmental Sustainability Targets

Setting clear, understandable and achievable goals will focus the organisation – both as a global company and on a site level – on activities and projects that will see the company closer to reaching the environmental sustainability goals. As AstraZeneca states, 'improvements can only be delivered through a collective effort across the company'.

Setting a global company goal is a great way of communicating to employees and to the rest of the world what is expected of each site and of the company as a whole.

Advance sustainable goals of 5 key industries

Food, Beverage & Consumer Goods

The Sustainable Development Goals (SDG) Industry Matrix highlights the following opportunities for shared value:

- Provide training and best practice guidance to small scale producers and retailers, including women-owned businesses, to improve the productivity, capacity, logistics and market efficiency of their operations.
- Reduce natural resources and energy used in agriculture and raw material production, processing, packaging and distribution.
- Reduce waste and emissions by reducing chemical by-products.
- Embed sustainability criteria in procurement processes and project evaluation.
- Find alternatives to palm oil.
- Take steps to measure, reduce and report climate exposure, and set measures of accountability for all parties involved in supply chains.
- Understand end-of-product use and disposal impacts.
- Monitor and reduce food loss and waste throughout the value chain.
- Develop consumer knowledge around sustainable agriculture and consumer products, and encourage recycling and sustainable disposal of products.
- Increase organizational awareness of the sustainability aspects of products, including product design, use and disposal.

Healthcare & Life Sciences

The SDG Industry Matrix highlights the following opportunities for shared value:

- Develop innovative micronutrient supplements and food fortification solutions to reduce vitamin and mineral deficiencies.
- Increase the proportion of people attending regular health checks.
- Continue improving early diagnostic techniques.

- Develop affordable preventive, diagnostic and curative healthcare solutions for neglected tropical diseases and other health challenges in low and middle income countries.
- Invest in telehealth and telecare to reduce patient travel and improve quality of care.
- Increase proportion of energy from renewable sources and increase energy efficiency in hospitals, healthcare centres, production plants and across the logistics value chain.
- Replace cold chain hydrofluorocarbons (HFCs) and derivative chemical refrigerants with natural refrigerants.
- Design medical devices with lower power consumption and improved end-of-product lifecycle recycling.
- Develop and implement improved processes to reduce, reuse and recycle water, raw materials, non-renewable minerals, energy, other inputs, by-products, hazardous waste, non-hazardous waste and packaging.
- Build environmentally sensitive hospitals, primary healthcare centres and production plants.

Industrial Manufacturing

The SDG Industry Matrix highlights the following opportunities for shared value:

- Develop more resource efficient machinery that generates less effluent, waste and pollutants.
- Apply a circular economy mind-set when designing products so that there is improved end-of-product lifecycle reuse and recycling.
- Incorporate innovative technologies, such as 3D printing, into manufacturing processes to reduce waste from long-run production and prototyping.
- Develop and implement improved processes (e.g. closed loop manufacturing) to reduce, reuse and recycle water, raw materials, non-renewable minerals, other inputs, by-products and waste.
- Source materials from sustainable sources (e.g. forestry products) and components with lower embedded energy.
- Increase energy efficiency in industrial manufacturing plants and across distribution networks.
- Increase the proportion of materials and components that are sourced locally in low and middle income countries.
- Build the resilience of suppliers in emerging economies to reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters.

Transportation

The SDG Industry Matrix highlights the following opportunities for shared value:

- Develop innovative transportation solutions, including pooled freighting services, which facilitate cost-effective movement of goods.
- Extend freight transport to underserved areas, for example, developing inland marine access points.
- Increase the energy efficiency of vehicles, vessels, rail rolling stock and aircraft, and accelerate the transition to transport powered by renewable energy (including development of next generation biofuels).
- Achieve zero defect production in order to minimize resource wastage and costly product recalls.
- Replace hydrofluorocarbons (HFCs) with natural refrigerants for transportation of food, vaccines, pharmaceuticals and other products requiring refrigeration.
- Reduce injuries, fatalities and losses from road traffic and railway accidents through the improved design, maintenance and operation of vehicles and trains (including autonomous vehicles), improved infrastructure, and road safety programs.

Energy, Natural Resources, Chemicals

The SDG Industry Matrix highlights the following opportunities for shared value:

- Collaborate with governments and other stakeholders to extend electricity grids to underserved communities including fragile states.
- Provide off-grid communities with access to affordable renewable energy (e.g. through low-carbon micro-grids or low-cost community solar systems).
- Develop and scale breakthrough technologies to accelerate the transition to a higher share of renewable energy (solar, wind, hydro, geothermal and biomass) in the global energy mix.
- Collaborate with industrial manufacturers to substantially increase the capacity and efficiency of power storage systems.
- Reduce and eliminate routine flaring in oil production.
- Reduce methane emissions along the gas value chain.
- Develop and implement improved processes to reduce inputs, i.e. raw materials, water, non-renewable minerals, etc.
- Source materials and raw inputs with lower embedded energy.
- Minimize waste and effluent resulting from production, and improve recycling and reuse of outputs.

- Invest in research and development to expand the application and cost-effectiveness of chemical bio-alternatives (e.g. to replace single use plastics).
- Develop and scale new energy technologies, chemicals and production methods that reduce contamination and air and water pollution.
- Ensure mines and production facilities are resilient to extreme climatic events.
- Share health and safety innovations and best practices with other industry stakeholders to minimize the risk of injury, illness and fatality from hazardous chemicals, air pollution, road collisions, mine collapses and other industrial accidents. (https://www.lenzing.com/sustainability/sustainability-management/sustainability-targets)

Adoption of Environmental Policies

Formulated policies have to be adopted by relevant institutions of government in order to be put into effect. Government regulations are effectively rules that define the bounds of legal behavior. Most regulations are expressed in a natural language, a form that require some interpretation. These are rules a government puts in place to restrict and control people's behavior. The intent it so improve all our lives.

Sensible, evidence-based regulations that respect the fundamental role of free-market competition can provide vital public benefits – such as protecting the environment, public health and safety, civil rights, consumers, and investors.

The International Efforts

The club of Rome stressed on limits to growth and highlighted issues such as sustainability and ecological balance. The worldwide concern for environmental degradation found expression in 1972 at the U. N. conference on Human Environment. Osborn's 'Limits to Growth' brought out in 1972, reported resource shortages, crowding, pollution, famines etc.

In 1979, a U. N. Symposium identified unsustainable consumption patterns and lifestyles as basic issues of environmental degradation, particularly in the richer countries.

It was truly observed by our late Prime Minister Smt. Indira Gandhi at Stockholm Conference in 1972, that environment cannot be developed in the condition of poverty, the major cause and effect of global environmental problems. Hence the new development paradigm is growth with equity, stability and sustainability.

However, it was the Brudtland Commission's titled "OUR COMMON FUTURE" (1987) – a landmark development thinking – which brought environmental issues to the fore. The commission came to the conclusion that, the relationship between economic growth and environmental conservation should be one of the complementarity and independence.

The idea of growth at all costs was replaced by the idea of sustainable development. 'Sustainable Development' became a key word and it's importance was reemphasized at the 'Earth Summit' held at Rio in 1992. The prime concern in all countries at present is to make environmental dimensions an integral part of their developmental plans.

Beginning of Policy Making in India

Pre-independence period (1853 to 1947)

- Shore Nuisance (Bombay and Kolaba) Act, 1853
- The Elephants Preservation Act, 1879

- The Fisheries Act, 1897
- The Factories Act, 1897
- The Bengal Smoke Nuisance Act, 1905
- The Bombay Smoke Nuisance Act, 1912
- Wild Birds and Animals Protection Act, 1912

Independence to the Stockholm Conference (1947-1972)

- The Factories Act, 1948

Post Stockholm Conference to Bhopal disaster (1972-1984)

- The Wildlife Protection Act, 1972
- Water (Prevention and Control of Pollution) Act, 1974
- Air (Prevention and Control of Pollution) Act, 1981
- The Forest (Conservation) Act, 1980
- Environmental Protection Act, 1986
- The Motor Vehicles Act, 1988
- The National Environment Tribunal Act, 1995
- The National Environment Appellate Authority Act, 1997
- The National Environment Policy, 2006
- National Forest Policy, 1988
- National Conservation strategy and Policy Statement on Environment and Development, 1992
- Policy Statement on Abatement of Pollution, 1992
- National Agriculture Policy, 2000
- National Population Policy, 2000
- National Water Policy, 2002

Advantages of Regulation:

- **Better working conditions:** One important advantage of regulations is that they can lead to better working conditions for employees. In many countries, there are strict regulations in place that determine how many hours an employee is allowed to work at the maximum. Moreover, there are also plenty of regulations in place that aim to protect workers from dangers or unhealthy work environments.

- **Protection of human rights:** Regulations also aim to protect all kinds of human rights. For instance, there are regulations in place that try to prevent the social isolation of minorities.
- **Crucial for the energy transition process:** The transition from fossil fuels to renewable energies is crucial in order to slow down global warming and to reduce all kinds of pollution. In order to successfully transit to green energies, governments around the world have to set strict regulations and give firms an incentive to invest in those green technologies.

- **Environmental benefits of regulations:** There are also many environmental benefits that can come along with strict regulations. For instance, governments can introduce regulations that limit the amount of greenhouse gases that are emitted into our atmosphere, which would slow down global warming to a certain extent. Moreover, governments could also set maximum pollution levels, which would further benefit our environment in various different ways.

- Working transportation systems
- Assurance of minimum qualification levels
- May provide social security for the poorest among us
- Health improvements for the general public
- Important for a sophisticated economic framework
- Holding people accountable for their action
- Avoidance of business monopolies
- Assurance of tax revenue
- Safety improvements

Regulations are indispensable to the proper functioning of economies and societies. They underpin markets, protect the rights and safety of citizens and ensure the delivery of public goods and services. At the end of the day, the formulation of public policy involves a process of making good decisions, for the public good.

References

1. Allakhverdiev, S. I. Kreslavski, V. D. Thavasi, V. Zharmukhamedov, S. K. Klimov, V. V. and Nagata, T. 2009. Hydrogen photo-production by use of photosynthetic organisms and biomimetic systems, *Photo-chemical Photo-biological Science,* 8:56-148.
2. Anthony, J. Buonicore, and Wayne. T. Davis. Air Pollution Engineering Manual. *Van Nostrand Reiholod, New York, USA.* [This manual depicted the air pollutant sources and their emission characteristics]
3. Aslam, M. Srivastava, R. S. Minocha, A. K. and Gupta, R. G. 1994, Air pollution hazards from brick kilns, *Journal of the Institution of Engineers (India), Environmental Engineering Division*.74: 83–87.
4. Amutha Bharathiar K., 2017. Sustainable chemical management and zero discharges, *University, Coimbatore, India.* 348-366.
5. Alessandra, N. Enrico, C. Giulio, D. S. Andrea, T. 2018. Industrial Sustainability: Modelling Drivers and Mechanisms with Barriers, Journal of Cleaner Production, 1-41.
6. Akumu, O. 2006. Sustainability prospects for water utilities privatization in Kenya. *International Journal of Technology Management and Sustainable Development* 5(3): 271-280
7. Abd Rahman, N. A. Daut, B. A. and Masrom, N. R. 2018. Industrial Solid Waste Management for Better Green Supply Chain. *International journal of Technology.*
8. Anita S. Abuja, Sachin D. Abda, 2015. Industrial Hazardous Waste Management by Government of Gujarat, International Multidisciplinary Research Journal.
9. Altaee, A., Zaragoza, G., van Tonningen, H.R., 2014. Comparison between forward osmosis-reverse osmosis and reverse osmosis processes for seawater desalination. *Desalination 336*, 50–57.
10. Al-Obaidani, S., Curcio, E., Macedonio, F., Di Profio, G., Al-Hinai, H., Drioli, E., 2008. Potential of membrane distillation in seawater desalination: thermal efficiency, *sensitivity study and cost estimation. J. Memb. Sci*. 323, 85–98.
11. Adler, R.W. Landman, J. C. and Cameron, D. M. 1993. The Clean Water Act 20 years later Washington, DC: *Island Press.*
12. Bataineh K.M., 2016. Multi-effect desalination plant combined with thermal compressor driven by steam generated by solar energy. *Desalination 385*, 39–52.
13. Bergstra, A.D. Brunekreef, B. and Burdorf, A. 2018. The effect of industry-related air pollution on lung function and respiratory symptoms in school children Arnold, *Environmental Health.* 17(30): 1-9.
14. Bhanarkar, a. D. Gajghate, d. G. And hasan, m. Z. 2002. Assessment of air pollution from small scale industry, *National Environmental Engineering*

Research Institute (NEERI), Air Pollution Control Division, Nehru Marg, Nagpur, India. 80: 125–133

15. Buncefield Major Incident Investigation Board, 2008. "The Buncefield Incident, 11 December 2005", the Final Report of the Major Incident Investigation Board, United Kingdom, *The Office of Public Sector Information, Richmond, Surrey.* 1.
16. Bethesda, M. D. Environmental Monitoring, 2004. A Comprehensive Handbook, *DHI publishing*, USA.
17. Bluglacier (https://bluglacier.com/why-is-sustainability-important/).
18. Brussels, 1999. Commission staff working paper on sustainable development, European Commission, 1-17.
19. Changming, L. and Zhikai, C. 2001 Reports Collection on Water Resources Stratagem for Sustainable Development in China, Beijing: *China's Hydrology and Electricity Press*, 2: 4-9.
20. Chafidz A., Kerme E.D., Wazeer I., Khalid Y., Ajbar A., Al-Zahrani S.M., 2016. Design and fabrication of a portable and hybrid solar-powered membrane distillation system, *Journal of Cleaner Production* 133, 631–647.
21. Census-India, 2012. Census of India, 2011. The Governement of India, New Delhi, India.
22. Cole, M.A. 2000. Air pollution and 'dirty' industries: How and why does the composition of manufacturing output change with economic development, *environmental and resource economics.* 17(1): 109-123.
23. Cole, M. A. Elliott, R. J. R and Shimamoto, 2004. Industrial characteristics, environmental regulations and air pollution, *Journal of Environmental Economics and Management*. 50: 121–143
24. Common Effluent Treatment Plant A solution or a problem in itself Main points for CETP paper (toxicslink.org). On 02/06/2021
25. Causes, Effects and Solutions to Industrial Pollution on Our Environment (Industrial Pollution - Causes, Effects and Prevention | Earth Reminder) on 08-06-2021
26. Causes, Effects and Solutions to Industrial Pollution on Our Environment (Causes, Effects and Solutions to Industrial Pollution on Our Environment - Conserve Energy Future (conserve-energy-future.com)) on 08-06-2021.
27. CPCB, 2003.Inventorisation of Hazardous Waste Generating Units in Orissa, Hazardous Waste Management Series Hazwams, p93.
28. C. Visvanathan, 1996.Hazardous waste disposal, Resource., Conservative., Recycling., (16):201-212
29. CENR (Committee on Environment and Natural Resources). 1997.Integrating the nation's environmental monitoring and research networks and programs: a

proposed framework. Washington, DC: The White House National Science and Technology Council, Committee on Environment and Natural Resources.

30. Diana Starovoytova, 2016. Potential of Roof Rain Water Harvesting at an industrial setup. *Journal of Environment and Earth Science.*
31. D. A. Rubinos and G. Spagnoli, 2018. Utilization of waste products as alternative landfill liner and cover materials, A critical review, Environmental Science Technology, 48(4), 376-438.
32. Demin, A.P. 2000. Trends in water supply and water conservation in Russia, *Water Resource review article*, 27 (6) 670–687.
33. Demirbas, A. 2009. Political, economic and environmental impacts of biofuels: a review. *Applied Energy* 86(108):1-17.
34. Dragone, G. Fernande, B. Vicente, A. A. and Teixeira, J. A. 2010. Third generation biofuels from microalgae. In: Mendez-Vilas A, editor, *Current research, technology and education topics in applied microbiology and microbial biotechnology*, 55-66.
35. EIA notification. 1994. MoEFCC, GOI, New Delhi.
36. EIA notification. 2006. MoEFCC, GOI, New Delhi.
37. Fatima Mansour, Sabla Y., Alnouri, 2019. End-of-Pipe Zero Liquid Discharge Networks for different brine water qualities, *Department of Chemical and Petroleum Engineering, American University of Beirut.* dx.doi.org/10.1016/B978-0-12-818634-3.50246-0.
38. Fane T., Macintosh P., Leslie G., 2004. Water reclamation, remediation and cleaner production with nanofiltration, *Nanofiltration, Elsevier, Oxford, UK.* pp. 287–304.
39. Gerpen, V. 2005. Biodiesel processing and production. *Fuel Process Technology*, 86(10): 97-107.
40. Gronwall, J., Jonsson, A.C., 2017. Regulating effluents fromIndia's textile sector: newcommands and compliance monitoring for zero liquid discharge. *Law Env't Dev. J.* 13.
41. Goyal, R. K. Tiwari, G. N. 1999. Performance of a reverse flat plate absorber cabinet dryer: a new concept, *Energy Conversion Management*, 40(4):385–92.
42. Gupta, R. Chaudhari, B. and Wate, S. R. 2008. Overview on attenuation of industrial air pollution by greenbelt.
43. Guidelines for developing greenbelts, CPCB, 2000. PROBES/75/1999-2000
44. Handbook of Environmental Procedure and Guidelines. 1994. MoEFCC, GOI, New Delhi.
45. Handbook of Forest Conservation Act, 1980. And Forest Conservation Rules, 2003 (Guidelines and Clarification) 2019. MoEFCC, GOI, New Delhi.

46. Heng, Y. Z. 2012. Study on the Circular Utilization of Water Resource in Three Industries, *Research Center of Regional Economy Shandong University of Finance and Economics Jinan,* 1-4.
47. HAO, J. and LI, G. air pollution caused by industries, *Department of Evironmental Sciences and Engineering, Tsinghua University, Beijing 100084, P.R.China.* 1: 171-190.
48. Heinsohn, R. J., and Kabel, R. L. (1999). Sources and Control of Air Pollution. *Prentice Hall, Upper Saddle River, New Jersey, USA*. [It discusses major air pollutant source characteristics].
49. Howarde and Hesketh (1996). Air Pollution Control—Traditional and Hazardous Pollutants. *Technomic Publishing Company, Inc. Pennsylvania, USA*. [It covers the main air pollutants and their control].
50. Innovative uses of wind energy (5 Innovative uses of wind energy and the countries using them - Green Diary - A comprehensive guide to sustainable hacks, green tips, and eco suggestions) on 12-06-2021.
51. Industry Scenario (Renewable Energy in India - Indian Power Industry Investment (investindia.gov.in)) on 12-06-2021.
52. "Indicative Guidelines on Techno-economic feasibility of Implementation of Zero Liquid Discharge (ZLD) For Water Polluting Industries" Central Pollution Control Board (December, 2014).
53. Inclusive and sustainable industrial development, United Nations Industrial Development Organization (UNIDO), (https://www.unido.org/inclusive-and-sustainable-industrial-development)
54. Ivan Secerov, Dragan Dolinaj and Zarko Zivanov, 2018. Environmental Monitoring Systems Review and Future Development, Wireless Engineering and Technology.
55. Jaspal Singh and Vandana Bharti, 2017. A Review on Solid Waste Management Methods and Practices in India.
56. Judd S., Jefferson B., 2004, Industrial effluent recycling in the power industry, *Ultrapure Water* 21 (4) 37–42.
57. Jun, X. Yizhong, Z. 2002. The Measurement of Water Resources Security: A Study and Challenge on Water Resources Carrying Capacity. *Journal of Natural resources,* 17(3): 262-269.
58. Khan, S. A. Rashmi, Hussain, M. Z. Prasad, S. and Banerjee, U. C. 2009. Prospects of biodiesel production from microalgae in India. *Renewable Sustainability Energy Review article*, 13(23): 61-72.
59. Kumar, S. and Meena, R. L. 2017. Renewable Energy Sources - Policies in India, *International Journal of Applied Environmental Sciences,* 12(2): 293-297.

60. Kvamsas, H. Neby S, Haarstad H, Reeve M. S. Schrage, J. 2020. Using collaborative hackathons to coproduce knowledge on local climate adaptation governance, Current Research in Environmental Sustainability 3: 1-9.
61. Kalogirou, S. 2003. The potential of solar industrial process heat applications, *Applied Energy*, 76(4):337–61.
62. Li, B. He, M. Gao, F. and Zeng, Y. 2021. The impact of air pollution on corporate cash holdings, *School of Economics and Management, Beijing University of Chemical Technology, Beijing, 100029, China.* 1-9.
63. Little, A. 1975. Water Supplies and Treatment and Disposal of Effluents. Textile Institute, London. UK. 21-49
64. Liu, H. F. David, Liptak. and G. Bela, 1997.Environmental Engineers Handbook, p1431.
65. Marianne, B, Ludovic, M. and Luc, P. A. 2010. Catherine, D. Serge, Multi objective optimization of industrial water networks with contaminants, *Computer Aided Chemical Engineering,* 28 (1): 859-864.
66. Mekhilefa, S. Saidurb, R. Safari, A. 2011. A review on solar energy use in industries, *Renewable and Sustainable Energy Reviews*, 15:1777–1790
67. Mortar, R. Block, C. and Vandecasteele, C. 2007. Water management in the Flemish steel industry: The Arcelor Gent case, *Cleaner Technology Environmental Policy*, 9 (4): 257-263.
68. Maps and other practices about ZLD https://data.gov.in/catalog/production-textile-products-india. On 02/06/2021.
69. Michael, D. L. Buchigham, P. L and Evans, J. C. 1994.The Environment Hazard Management Group, Hazardous Waste Management.
70. M. D. LaGrega, P. L Buckingham and J. C. Evans, 2010. Hazardous Waste in Hazardous Waste Management, Waveland Press, Illinois.
71. Muhammad Yaqub, Wontae Lee 2019. Zero-liquid discharge (ZLD) technology for resource recovery from wastewater: *Science of the Total Environment*, 681 551–563
72. Manjari Maheswari, Sunita Dubey 2000 Common Effluent Treatment Plant A solution or a problem in itself, *Toxics Hotspot- A Greenpeace Investigation of Gujarat Industrial Estates*, pp.21-243.
73. Mondal, P. article, What is the Importance of Sustainable Development, https://www.yourarticlelibrary.com/environment/what-is-the-importance-of-sustainable-development/9910.

74. MoUD, 2011. Report on Indian Urban Infrastructure and Services. High Powered Expert Committee of the Ministry of Urban Development, the Government of India, New Delhi, India.
75. Makes, M. Odour, R. Odhiambo, J. 2007. Green Water Management Handbook, Rainwater harvesting for agricultural production and ecological sustainability. World Agroforestry Center.
76. Meka Srinivasarao and Arti Pamnani, 2014. Municipal Solid Waste Management in India. *Journal Impact Factor.*
77. M. N. Rao, R. Sultan and S. H. Kota, 2017.Hazardous waste in solid and Hazardous Waste Management, Butterworth-Heinemann.
78. Nath, A. 2021. Forestalling and Decreasing Contamination to Improve Air Quality Universally, *Journal of Pollution Effect and Control.* 9(5): 290.
79. NEERI, 1993. Carrying Capacity Based Development Planning for National Capital Region', *NEERI, Nagpur, India.* 1-14.
80. National Inventory of Hazardous Wastes Generating Industries & Hazardous Waste Management in India,2009. Delhi: Central Pollution Control Board Hazardous Waste Management Division Delhi.
81. National statistical office Ministry of statistics and programme implementation government of India New Delhi, Energy statistics 2020. on 12-06-2021.
82. Pittner G.A., 1993. High purity water production using reverse osmosis, *Reverse Osmosis,Van Nostrand Reinhold, New York, NY,* pp. 334–363.
83. Onishi V.C., Carrero-Parreño A., Reyes-Labarta J.A., Ruiz-Femenia R., Salcedo-Díaz R., Fraga E.S., Caballero J.A., 2017 a. Shale gas flow back water desalination: single v/s multiple-effect evaporation with vapor recompression cycle and thermal integration, *Desalination 404,* 230–248.
84. Pedersen, G. C. and Bhattachararjee, P. K. 1997. scrubbers with level head, *journal of chemical engineering*, 104(11).
85. Proctor, D. Morse, R. N. 1977. Solar energy for the Australian food processing industry. *Solar Energy*, 19:63–72.
86. Patel, U. and Ahluwalia, I. J. 2018. Solid Waste Management in India An Assessment of Resource Recovery and Environmental Impact. *Indian Council for Research on International Economic Relations.*
87. Raja, S. A. 2011. Robinson smart DS, Lee CLR. Biodiesel production from jatropha oil and its characterization. *Research Journal of Chemical science,* 1(8): 1-7.
88. Razzak, S. A. Hossain, M. M. Lucky, R. A. Bassi, A. S. and Lasa, D. H. 2013. Integrated CO2 capture, waste water treatment and biofuel production by microalgae culturing-a review, *Renewable Sustainability Energy Review article,* 27: 53-622.

89. Rodionova, M.V. Poudyal, R.S. Tiwari, I. Voloshin, R.A. Zharmukhamedov, S.K. Nam, H.G. Zayadan, B.K. Bruce, B.D. Hou, H.J.M. Allakhverdiev, S.I. (2016)Biofuel production: Challenges and opportunities, *International journal of hydrogen energy*, 1-12.
90. Roy, S. Das, D. 2015. Liquid fuels production from algal biomass. In: Das D, editor. Algal bio-refinery: an integrated approach. *Capital Publishing Company*, 27-96.

91. Royan, F. 2021.Top 5 Trends for Environment & Sustainability in 2021, Frost & Sullivan, (https://www.frost.com/frost-perspectives/top-5-trends-for-environment-sustainability-in-2021/)

92. Rinaldi, N. U. 1995. Wet scrubbers: choose the best chemical reagent, *journal of environmental world*, 1(2).
93. Rizwan S.A. Nongkynrih, B. and Gupta, S. K. 2013. Air pollution in Delhi: Its Magnitude and Effects on Health, *Indian Journal of Community Medicine.* 38(1): 4-9.
94. Sarath, K. Goel, G. R. Pant, P. 2014. Nature of air pollution, emission sources, and management in the Indian cities, *Atmospheric Environment:* 95: 501-510.
95. Serrano, A. J. B. Mannan, M. S. and Laird, C.D. 2014. A quantitative assessment on the placement practices of gas detectors in the process industries, *Journal of Loss Prevention in the Process Industries.* 35: 339-351.
96. Singh, G.S. 2021. Pandemic: An Opportunity to Reduce Air Pollution, *Modern Chemistry Application*. 9(4): 298.
97. Sharma Mona, Vikas Mohan and Bansal Deepak, 2017. Reduction and Management of Waste in Hotel Industries.
98. Somyadeep Baksi, B. P. Yadav, Abhishek Nandan and Debajyoti Bose, 2017. Recent Scenario of Solid Waste Management in India.
99. Shahzad, U. 2017. The Need for Renewable Energy Sources, *International Journal of Information Technology and Electrical Engineering,* 16-18.
100. Soteris, K. A. 2004. Solar thermal collectors and applications. *Progress in Energy and Combustion Science.* 30(3):231–95.
101. Stover R.L., 2013. Close circuit desalination achieves high recovery at Kranji, *World Water Water Reuse Desal*. 4 (4) 12–13.
102. Salcedo R., Antipova E., Boer D., Jiménez L., Guillén-Gosálbez G., 2012. Multi-objective optimization of solar Rankine cycles coupled with reverse osmosis desalination considering economic and life cycle environmental concerns. *Desalination 286*, 358–371.

103. Standard terms of reference for EIA/EMP report for projects /activities requiring environmental clearance under EIA notification, 2006. MOEFCC, 2015
104. Shrikant Ahirrao, 2014. Zero Liquid Discharge Solutions, *Industrial Wastewater Treatment, Recycling, and Reuse.* 490-520.
105. Sustainability at University of California, Los Angeles **(**UCLA) (https://www.sustain.ucla.edu/what-is-sustainability/). November 22, 2021.
106. Svetlana B. Zueva, Francesco Ferella, Giuliana Taglieri, Ida De Michelis, Inna Pugacheva, Francesco Vegliò. 2020. Zero-Liquid Discharge Treatment of Wastewater from a Fertilizer Factory, *Sustainability, 12, 397; doi:10.3390/su12010397.*
107. Tiezheng Tong, Menachem Elimelech, 2016. The Global Rise of Zero Liquid Discharge for Wastewater Management: Drivers, Technologies, and Future Directions, *Research gate, American Chemical Society,* DOI:10.1021/acs.est.6b01000 Environ. Sci. Technol. 2016, 50, 6846−6855
108. The concept note For Challenges against implementation of ZLD http://www.moef.nic.in/sites/default/files/Effluents%20from%20textile%20Industry.PDF. On 02/06/2021
109. The most common uses of renewable energy in the industry (4 Ways the Mining Industry Uses Renewable Energy | Anglo American). on 12-06-2021.
110. U Sridharan, V. P. Upadhyan and Shantanu K Dutta, 2006. Environmental Management of Industrial Hazardous Wastes in India, Indian journal of Environmental Health.
111. Vijay Kumar, V. Swathy, S. Radhika, R. Fasi Khan, M. A. and Dr. Chandrashekar, B. 2019. Green Belt Requirement for New and Expansion Project for Obtaining Environmental Clearance in India. *Research India Publication.* 14(5): 475-487
112. Viviani C., Onishi, Ruben Ruiz-Femenia, Raquel Salcedo-Díaz, Alba Carrero Parreño, Juan A., Reyes-Labarta, José A., 2017. Multi-Objective Optimization of Renewable Energy-Driven Desalination Systems Caballero, *Institute of Chemical Process Engineering, University of Alicante.* dx.doi.org/10.1016/B978-0-444-63965-3.50085-4
113. Voloshin, R. A. Kreslavski, V. D. Zharmukhamedov, S. K. Bedbenov, V. S. Ramakrishna, S. and Allakhverdiev, S. I. 2015. Photo electro chemical cells based on photosynthetic systems: a review, *Bio-fuel Resources Journal,* 6: 35-56.
114. Vesilind, P. 1990. Environmental Pollution Control. Butterworth, U.S.A.
115. Walton, D. 1995. Building Construction Principles and Practices. Macmillan Education, U. K.
116. What is Zero Liquid Discharge & Why is it Important? 2018 http://www.ZERO%20LIQUID%20DISCGARGE/What-is-Zero-Liquid-

Discharge-Why-is-it-Important-2.pdf - projects@saltworkstech.com. On 02/06/2021.

117. What is sustainable development, and why is it so important? (http://emeraldbe.com/sustainable-development-important/) 2017.

118. World electricity generation by source in 2018. Total generation was 26.7 PWh. (Wind power - Wikipedia) on 12-06-2021.

119. Wang, l. Zhang, F. Pilot, E. Yu, J. Nie, C. D, I. Holdaway, J. Yang, L. Li, Y. Wang, W. Vardoulakis, S. and Krafft, T. 2018. Taking Action on Air Pollution Control in the Beijing-Tianjin-Hebei (BTH) Region: Progress, Challenges and Opportunities, *International journal of environmental research and public health.* 15(306): 1-27.

120. Zhengying, Q. andGuangdou, Z. 2001. Reports Collection on Water Resources Stratagem for Sustainable Development in China, Beijing, *China's Hydrology and Electricity Press,*1: 4-6.

121. Zou, D. and Cong, H. 2020. Evaluation and influencing factors of China's industrial water resource utilization efficiency from the perspective of spatial effect, *Alexandria Engineering Journal*, 6(53): 1-10.

122. https://www.cpcb.nic.in

123. https://www.kspcb.gov.in

124. https://vikaspedia.in

125. http://www.unep.org/gemswater