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ROLE OF GREEN TECHNOLOGY IN DESIGNING SUSTAINABLE ENGINEERING FRAMEWORK-A REVIEW

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Abstract--**Since the stone age, humanity has discovered different phenomenon by observing nature and has utilized them for its welfare. Today, as we proceed towards erudite civilization, more resources are required to aid our advancement in technology. Hence, the energy crisis and ecocide have taken a significant toll on us and it has alarmed many scientific societies all around the world. In regards to sustainable growth aspects, UNESCO has announced 17 Sustainable Development Goals to help and guide nations to align their policies while keeping sustainability in mind. In this SDG list, 5 of the goals are related to the energy crisis highlighting its urgency. As future generation engineers, practicing sustainability engineering is essential to ensure safe energy production and resource sustainability. To battle this havoc of energy crisis, green energy emerged as a weapon for engineers but its proper utilization is still a mystery to those in the fieldwork. This paper, with help of case studies, is intended to help understand the role of green technology in the professional field while practicing sustainability engineering.**

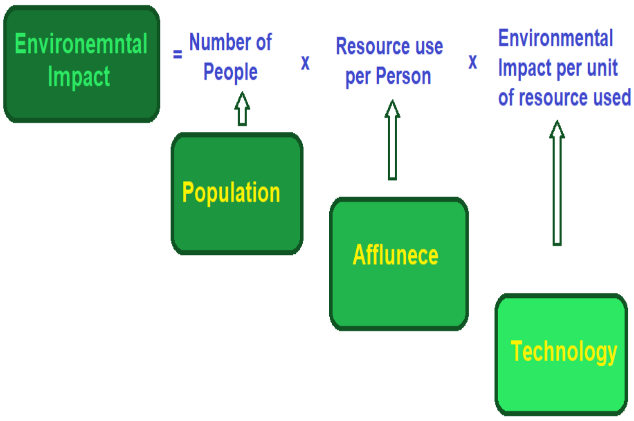
Keywords- **Green Technology, Sustainability Engineering, Energy, Sustainability, Sustainable Development Goals, Energy Crisis**

I. INTRODUCTION

TThere is a great reliance on engineering to solve environmental problems around the world today, still when our world has been getting deteriorated by the same technology. The engineering fixes of the past we use till the date will not do any help to solve energy crisis and environmental damage anymore. Yet the sorts of technology changes that would be necessary to keep up with and counteract the growing environmental damage would have to be fairly dramatic. The organization for Economic Cooperation and Development, OECD, found that most investment in pollution control was being used for end-of pipe technologies, with only 20 per cent being used for green production. Green technologies are not always available and, even when they are, companies tend not to replace their old technologies until they have run their useful life. Also, companies like to play it safe when it comes to investment in pollution management even when better output conditions are promised. Hence the question remains, can such a radical redesign of our engineering systems occur within working sector and will it practical to use these green technologies in work? At the heart of the debate over the potential effectiveness of sustainable development is the question of whether technology change, even if it can be achieved, can reduce the impact of energy crisis & ecocide sufficiently to ensure reliability, feasibility and sustainability in field work.

II. LITERATURE REVIEW

According to the OECD report entitled "Towards Green Growth," policymakers should follow the concept of green growth. The economy needs to be flexible, dynamic, and efficient when using resources and imposing a mutual effect on the environment for its preservation. Innovation and investment are seen as drivers for the green technology development [3]. A development forecast is based on a common scenario (increasing productivity, innovation, and technology) that additionally brings an extra range of ecological advantages. Indirectly-mentioned threats such as climate change, the loss of biodiversity, and food shortages undermine the promotion of growth. The social pillar of sustainable development and green growth is also disregarded.



(Source: Beder, Sharon, https://ro.uow.edu.au/artspapers/48)
Fig. 1. The factors determining environmental impact

It is green technology that stimulates sustainable development, which means identifying environmentally-friendly sources of growth, developing new environmentally-friendly industries, and creating jobs and technologies [4]. To achieve green growth, it is necessary to intensify investments and innovations that represent a foundation of sustainable development and open new economic opportunities [5]. Thus, the promotion of green economy requires thorough research on the conditions of its formation, system-forming factors, and its impact on national sustainable development. Parties that are interested in green economic development include business (which focuses on economic benefits), the authorities (which set environmental goals of sustainable development), and the public (which represents the interests of a social community) [6]. To achieve goals of sustainable development, innovations are needed [7]. The processes of green knowledge management play a special role in sustainable development, more specifically the creation, acquisition, exchange, and use of knowledge, as well as its impact on green technologies, eco-innovations, and the socio-economic dimension of sustainable development [8,9]. Sustainable innovation allows the company to keep up with technology. The sustainable green innovations are aimed at the generation of high-quality innovative products that can reduce environmental footprint. As long as environmental issues arise, the importance of sustainable green innovations will be widely recognized [10].

III. OBSERVATIONS

A. Sustainable Development Goals

A sustainable society is founded on equal access to nutritious food, clean drinking water, health care, smart shelter, education, energy, economic opportunities and employment. In this ideal society, humans live in harmony with their natural environment, conserving resources not only for their own generation, but also for their future generations.

This paper presents the methodological framework used in sustainable development. It is based on a Sustainable Development Goals (SDG) consisting of 17 sustainable development goals: SDG 1 (no poverty), SDG 2 (zero hunger), SDG 3 (good health and well-being), SDG 4 (quality education), SDG 5 (gender equality), SDG 6(clean water and sanitation), SDG7(affordable and clean energy), SDG 8 (decent work and economic growth), SDG 9 (industry, innovation and infrastructure), SDG 10 (reduced inequalities), SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), SDG 13 (climate action), SDG 14 (life below water), SDG 15 (life on land), SDG 16 (peace, justice, and strong institutions), and SDG 17 (partnerships for the goals). From among all SDGs, a set of goals was selected that is related to environmental sustainability: SDG 6, SDG 7, SDG 13, SDG 14, and SDG 15. These goals are as follows:

Goal 6. Ensure availability and sustainable management of water and sanitation for all.

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.

Goal 13. Take urgent action to combat climate change and its impacts.

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

B. Green Technology Aspects

Green Technology (GT) is environmental healing technology that reduces environmental damages created by the products and technologies for peoples' conveniences. It is believed that GT promises to augment farm profitability while reducing environmental degradation and conserving natural resources. Green technologies are sustainable technologies which will not create footprint when used for various processes/applications. Green technologies support the use of natural organic resources and avoid production of green gasses. They also consume less resource and do not support to increase the entropy of the universe. Green technologies do

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not support any kind of environmental degradation. They support automation of every process and hence avoid human intervention. Since they are do not support environmental degradation and contribute to creating the footprint, they are sustainable, improves the lifestyle of the people and contribute for human comfortability. The major technologies used in present day like Aircraft technology, Automobile technology, Biotechnology, Computer technology, Telecommunication technology, Internet technology, Renewable energy technology, Atomic & Nuclear technology, Nanotechnology, Space technology etc. can be made green using the principle of green technology. Such green technologies may contribute to solving problems of the society both basic and advanced kind of civilization. The objectives of green technologies in some of the basic and advanced fields of society are listed in table 1.

TABLE I
Objectives of green technologies in various areas of the society

S. N.	Area	Objectives of green technologies
1	Agriculture	To avoid environmental degradation in agriculturalprocesses.
2	Food Processing	To eliminate poisonous contents in food and to avoid green gas emission and environmental degradation in all food packaging processes.
3	Potable water	To large scale filter used water and sea water through green processes without environmental degradation.
4	Sustainable Energy	To develop technologies for harvesting potential natural energy sources to generate required energy to human civilization without degrading environment.
5	Consumer products	To produce variety of new generation consumer productswithout side effects and without degrading environment in any production, packaging and in actual use by consumers.
6	Automobiles	To produce energy efficient, zero emission automobilesusing renewable energy processes.
7	Construction	To build environment friendly, energy efficient, smart buildings.
8	Industrial Automation	To develop industrial processes which are environmental friendly, no green gas emission, recyclable waste products using green energy.
9	Computer& Information Communication	To develop and utilize environment friendly, recyclable electronic and computer components which uses renewable energy and efficient performance.
10	Education	Use of green technology in all education services.
11	Health	Use of green technology and green processes in all health and medical services.

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12	Aircraft & Space Travel	Use of green energy and green materials and environment friendly processes in air and space travel.

C. Sustainable Engineering

In this paper, main focus is given on how green technologies in the working sector can provide solutions to environmental problems while enhancing countries' competitiveness. Rising energy consumption and GHG emissions are major driving forces for the development of green technologies. Industry, transport and construction roughly account for equal shares of energy consumption and GHG emissions of around 30 percent in the projections of the International Energy Agency in the World Outlook 2012. Hence, cases in these three sectors can be focused.

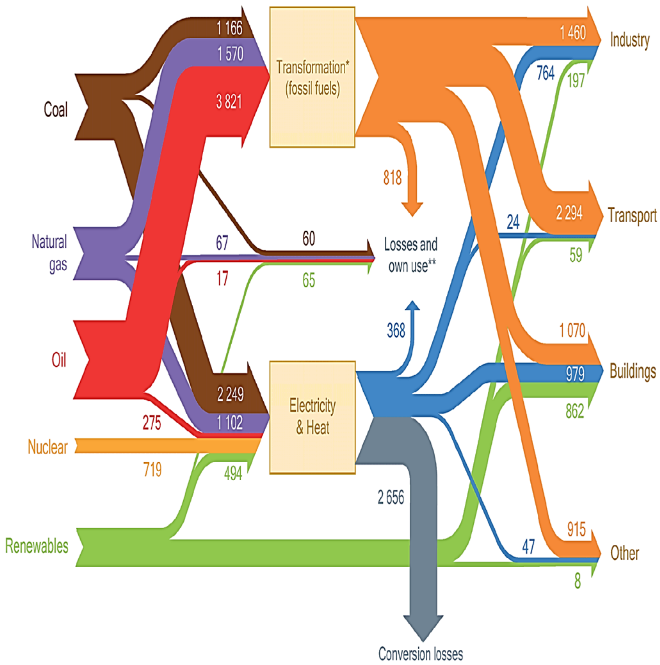

Fig. 2. The importance of industry in the global energy system 2010

(Source: IEA, 2012)

TABLE II
Change in energy demand from year 1990 & projected demand up to 2035

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	Energy demand (Mtoe)							Shares (%)		CAAGR (%)
	1990	2010	2015	2020	2025	2030	2035	2010	2035	2010-35
TFC	**6 275**	**8 678**	**9 565**	**10 223**	**10 742**	**11 241**	**11 750**	**100**	**100**	**1.2**
Coal	773	853	970	982	984	983	976	10	8	0.5
Oil	2 593	3 557	3 813	3 984	4 108	4 219	4 336	41	37	0.8
Gas	942	1 329	1 464	1 612	1 740	1 864	1 993	15	17	1.6
Electricity	833	1 537	1 802	2 047	2 255	2 463	2 676	18	23	2.2
Heat	333	278	293	303	305	305	305	3	3	0.4
Bioenergy	795	1 103	1 188	1 250	1 294	1 335	1 373	13	12	0.9
Other renewables	4	22	33	45	57	72	91	0	1	5.9
Industry	**1 809**	**2 421**	**2 790**	**3 035**	**3 203**	**3 355**	**3 497**	**100**	**100**	**1.5**
Transport	**1 568**	**2 377**	**2 596**	**2 778**	**2 935**	**3 093**	**3 272**	**100**	**100**	**1.3**
Buildings	**2 243**	**2 910**	**3 121**	**3 302**	**3 452**	**3 599**	**3 748**	**100**	**100**	**1.0**
Other	**655**	**970**	**1 057**	**1 107**	**1 152**	**1 194**	**1 232**	**100**	**100**	**1.0**

Case 1: Green Buildings (Implemented Framework)

A green building is a structure that is environmentally responsible and resource-efficient throughout its life cycle. These objectives expand and complement the classical building design concerns of economy, utility, durability, and comfort. Green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

i. Efficiently using energy, water, and other resources.
ii. Protecting occupant health and improving employee productivity.
iii. Reducing waste, pollution and environment degradation.

1. Typical Features of Green Buildings

a) Eco-friendly Building Materials:

At present, generation of fly ash in India is more than 60 million tonnes per annum. Fly ash as such is a pollutant but when used, as Building Material is Eco-friendly. Fly ash can be used for making a variety of building products some using simple low-cost processes and other high investment processes producing high quality products. The present state of manufacture of fly ash products is outlined below.

1) Clay Fly Ash Bricks.
2) Stabilized Mud Fly Ash Bricks.
3) Autoclaved Aerated Concrete.
4) Cellular Light Weight Concrete.
5) Cast-in-situ fly ash walls.

b) Green Power -Solar & Wind Energies

Optimum use of available solar energy and other forms of ambient energy in building designs and construction achieves Energy-Efficiency in Green buildings. Whatever combination of solar, wind, and utility power is available; the entire power system would be greatly enhanced by a reliable, zero maintenance, ultra-long life, and lower life cycle cost power storage and management system.

c) Water use Efficiency

1) Drip Irrigation

In Green buildings, the superstructure is constructed over a cellar which is used to capture the excess rainwater. The basement is below the ground level and stores the water where it is treated and cycled for use. This method has a low maintenance cost and is user friendly. It is highly viable in both flood prone and draught prone areas to store the water from rainy season for the summer.

A drip irrigation system delivers water to the crop using a network of irrigation equipment like mainlines, sub-mains and lateral lines with emission points spaced along their lengths.

2) Rain Water Harvesting

Rainwater harvesting is a technique used for collecting, storing, and using rainwater for landscape irrigation and other uses. The rainwater is collected from various hard surfaces such as rooftops and/or other types of manmade above ground hard surfaces.

2. Benefits Of Green Buildings

Buildings have an enormous impact on the environment, human health, and the economy. The successful adoption of green building strategies can maximize both the economic and environmental performance of buildings.

A. Environmental Benefits

- Enhance and protect biodiversity and ecosystems.

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- Improve air and water quality.
- Reduce waste streams.
- Conserve and restore natural resources.

B. Economic Benefits
- Reduce operating costs.
- Create, expand, and shape markets for green product and services.
- Improve occupant productivity.
- Optimize life-cycle economic performance.

C. Social Benefits
- Enhance occupant comfort and health.
- Heighten aesthetic qualities.
- Minimize strain on local infrastructure.
- Improve overall quality of life.

(Source: Karim Ayyad https://www.researchgate.net/publication/347471995)
Fig. 3. Benefits Of Green Buildings

Case 2: Cement production (Current Research)
Dry, semi-dry, semi-wet and wet processes are the four main process routes used in the production of cement. Dry processes are considerably more energy efficient but the choice of technology usually depends on the availability of raw materials.
Due to the widespread availability of dry materials, a considerable share of their production in developed countries is converted into dry processes. Dry processes are also the main choice of new plants or for plants seeking to expand or upgrade.
The energy-intensive wet process is still being used in some countries, but is being phased out in many countries. Most of the cement industry's energy use and CO2 emissions are linked to the production of clinker, the main component of cement produced by sintering limestone and clay. The electricity needed to crush and grind raw materials, the fuel required and the finished products have a high energy demand.

TABLE III
Production process and Energy consumption

Production Process	Energy Consumption (GJ/t Clinker)	
	Min	Max
Dry, multistage cyclone pre-heater and pre-calciner kilns	2.85	3.0
Dry process rotary kilns with cyclone pre-heaters	3.1	4.2
Semi-dry/semi-wet processes (Lepol kiln)	3.3	4.5
Dry process long kilns		5.0
Wet process long kilns	5.0	6.0
Shaft kilns (up to 100 t/d capacity)	3.1	4.2

Proven technological options with the potential to achieve considerable reductions in both energy use and CO2 emissions can be categorized into a) the use of energy-efficient technologies; b) the use of alternative raw materials and fuels, and c) reduction of the clinker content of cement through increased use of other blends. Other options are also emerging in the form of alternative cementitious materials and carbon capture and storage.

Proposed New Green Technologies

1) Carbon capture and storage CCS: This process is based on capturing carbon dioxide (CO2) from large point sources and storing it in such a way that it does not enter the atmosphere. Carbon capture and storage (CCS) for the cement industry involves capturing the CO2 arising from the combustion of fuels and from the treatment of raw materials and storing it away from the atmosphere for very long periods of time. This technology is emerging as the favored approach for CO2 abatement.

In principle, three basic technologies are known to capture CO2: pre-combustion capture, oxyfuel combustion and post-combustion capture. For the cement industry, oxyfuel combustion and post-combustion capture are considered alternative approaches. Many of the carbon capture applications are currently in demonstration or research phases. The transport and storage of compressed CO2 are available techniques, but are currently limited to specific applications. Experiences on a larger scale are not yet available. It should be noted that CCS costs are high, and the adoption of this technology in industry is highly dependent on policy intervention.

2) Renewables and smart grids: Renewables and smart grid options are a short-term solution for industrial manufacturing and imply a substantial reorganization of process management. However, such options are far from being mainstream in industrial applications and require substantial innovations in the organization of industrial processes. This implies:

• Use of wind or PV as sources of electricity. For example, the Lafarge company makes use of such alternative sources in Morocco to cope with high electricity prices and to ensure a stable supply of electricity
• Small concentrated solar power units (solar dishes of a size of 20-30 kW and more when modules are combined) can be used to provide process heat for industrial processes (medium temperature range)
• Performant solar collectors or absorber units could be used for low temperature heat or cooling ranges for both buildings and processes
• Use of industrial heat pumps
• Use of (sustainable) sources of biomass
• Biowaste could be used for selected processes
• Biogenic material may replace selected raw materials which are presently gained from oil-based chemistry.

Examples of possible changes to patterns of materials cycles in materials turnover could be:

1. Usage-centered business models (e.g. value for use)
2. Hybrid value adding (systematic integration of products and services in service packages)
3. Carbon-neutral economic activities (post-carbon economy)
4. Green chemistry
5. Dematerialized value adding
6. Interactive value adding (added value with an extensive contribution from customers/users)
7. Bionic process concepts (e.g. cascade models)
8. Personalized value-added chains with second generation bio-refineries
9. Cross-sectoral recyclable materials symbioses (e.g. zero-emission industrial parks).

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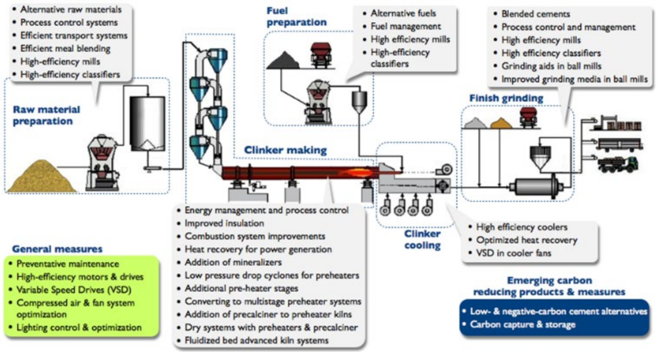

Fig. 4. Emerging carbon reducing products and measures

D. Incorporating Green Technology in Sustainability Engineering Framework

Many technologies like nanotechnology, next generation nuclear power, bio-fuels, bio-plastics, smart monitoring & prediction analysis, tidal energy etc. are some of the possible sustainable technologies for future. Engineers and scientists around the world are developing technological solutions aimed at reducing and eliminating everything that causes energy crisis and, therefore, ecocide.

Following are the recommended strategies for execution of green technologies in current engineering framework:

1. Wastewater treatment

In this field, there are few technological developments, but the existing ones are important. Key developments include membrane filtration, microbial fuel cells, nanotechnology, development of biological treatments and natural treatment systems such as wetlands. All these processes are used to make water drinkable or significantly reduce the presence of pollutants from what is discharged into the sea and rivers.

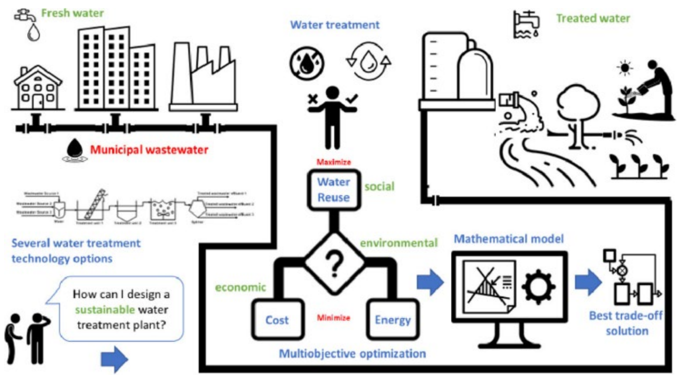

Fig. 5. Wastewater treatment and associated reuse, recycling

2. Elimination of industrial emissions

The management of air pollutants in industries can significantly reduce the greenhouse effect. Methane and carbon dioxide are substances that harm the environment. Industries such as chemical, petrochemical, pharmaceutical, automotive, etc. must eliminate their emissions so as not to cause serious environmental damage.

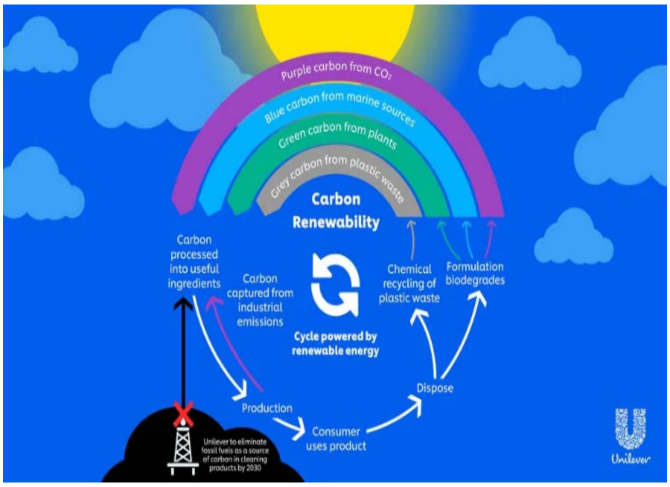

Fig. 6. Industrial emissions and Carbon Renewability

3. Recycling and waste management
The increase in household and industrial waste has been disproportionate. Managing solid waste is the commitment of companies as well as individuals. Outstanding technologies such as smart containers, automated food waste tracking systems and automated optical scanning technologies can help sort mixed plastics by separating them from others.

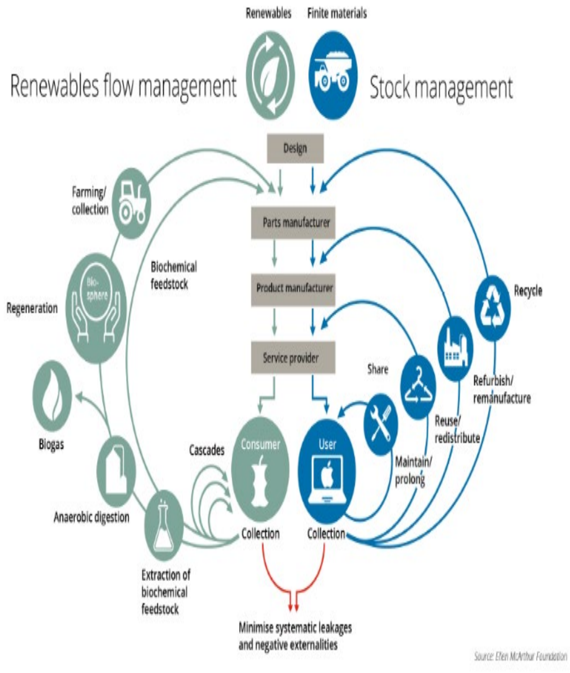

Fig. 7. Renewables flow and stock management

4. Waste-to-Energy
The generation of energy from waste, also called Waste-to-Energy, is technology that generates energy from garbage. We need to develop waste treatment solutions that generate energy in the form of steam, hot water or electricity that each company can later use for internal processes.

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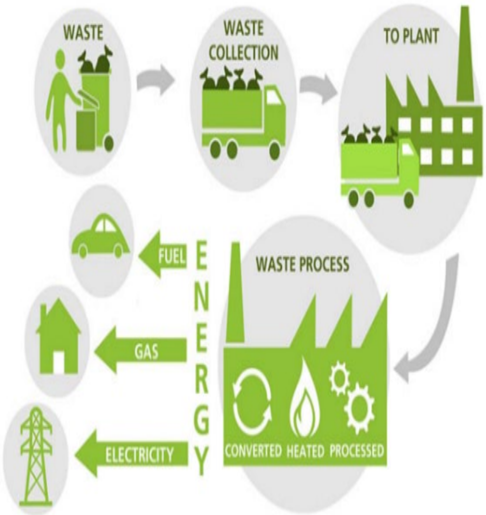

Fig. 8. Waste-to-Energy Concept

5. Self-sufficient buildings
Self-sufficient buildings are those constructions that are able to function by themselves by generating energy without the need of an external contribution. One way to achieve greater production with the same surface of photovoltaic panels is to incorporate intelligent solar tracking systems, thus obtaining an optimal use of radiation.

Fig. 9. Sustainable goals and Self-sufficient buildings

6. Vehicles that do not emit gases
Known as ecological vehicles, they are so called because their use does not negatively influence the environment and contributes to reducing the presence of polluting gases in the atmosphere, mainly carbon dioxide (CO_2), carbon monoxide

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(CO), nitrogen oxide (NOx), unburned hydrocarbons (HC) and compounds of lead and Sulphur dioxide.

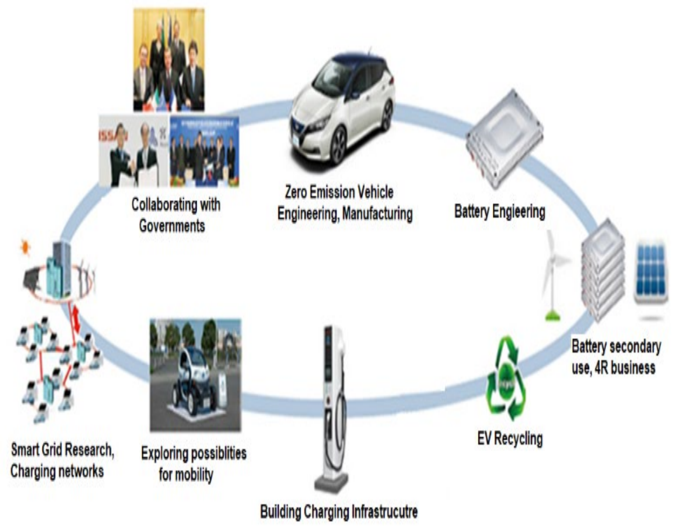
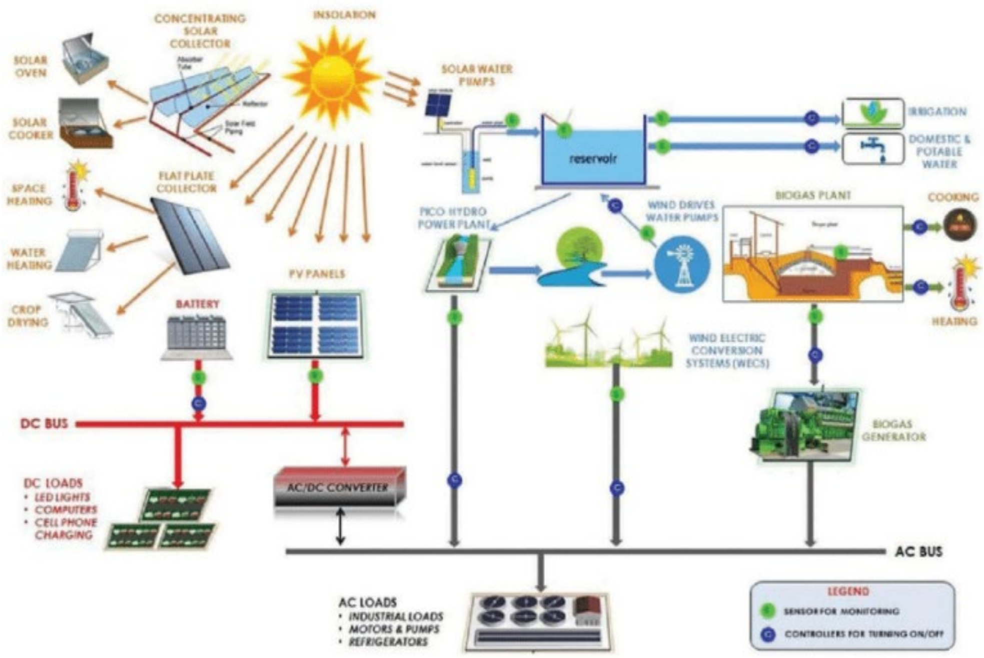


Fig. 10. Concept of zero emission vehicle.

7. Harnessing solar energy
Perhaps these are the systems that have been worked on and researched the most. Examples of solar energy conversion technologies are high vacuum tube for hot water, polypropylene collector for hot water, photovoltaic collector to produce electricity and solar streetlamps, among others. All those technologies aim to reduce dependence on energy from hydrocarbons and fossil fuels and promote greener solutions.



(Source: https://www.researchgate.net/publication/332404621)
Fig. 11. Harnessing solar energy

8. Generation of energy from the waves
The first wave energy management plant was built in Aguçadoura, Portugal, 8 km away from the coast. The plant has a capacity of 2.25 MW and is able to supply electricity to up to 1500 homes. The installation consists of steel tubes floating on the ocean surface, measuring 3.5 m in diameter

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and 150 meters long, called "Pelamis". Those components are semi submerged in the sea and are responsible for transforming the movement of the waves into electrical energy.

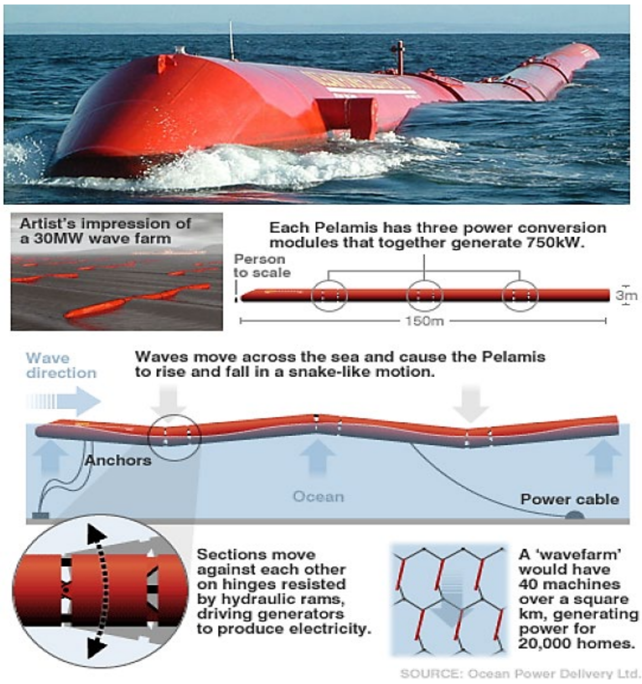

Fig. 12. wave energy management plant in Aguçadoura, Portugal

9. Vertical gardens and farms

The installation of vertical gardens in buildings also helps save energy and brings many benefits to the environment. Vertical gardens don't need watering routines that involve unnecessary use of water, and because they are installed along a wall, they reduce the intense hearing pollution that comes from the outside and even that one that you can generate. Moreover, it helps isolate the high temperatures that are presented by climate change, resulting in significant savings in energy, heating and air conditioning. If we extrapolate this technology to farms, we can save a lot of water and take care of the fertile soil. Today, there are vertical farms of up to 100 hectares.

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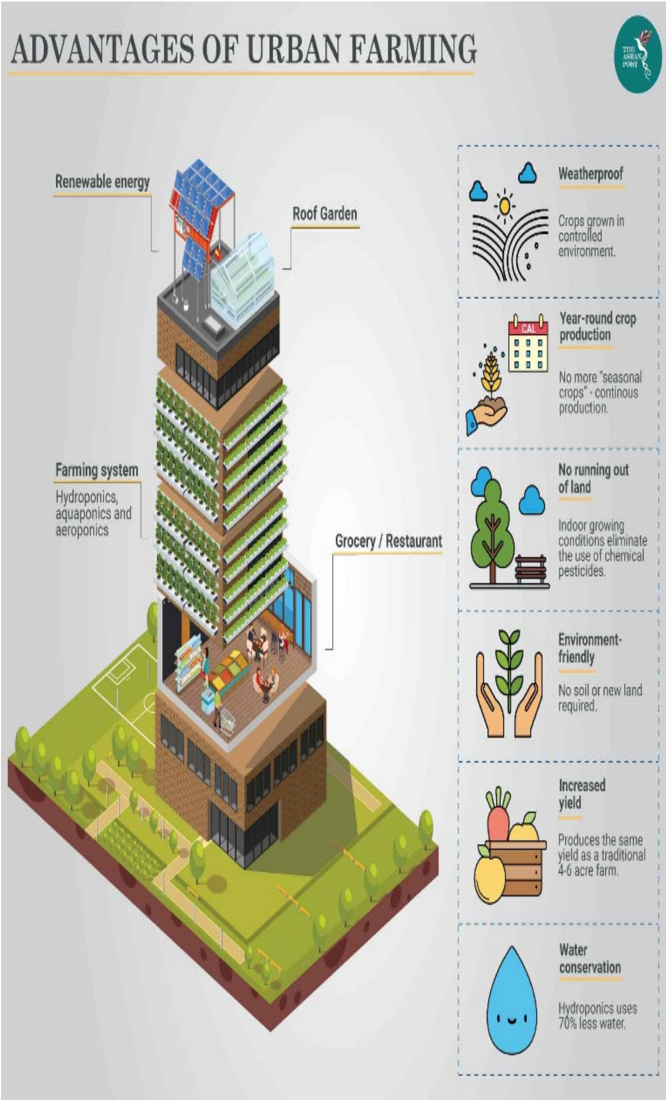

Fig. 13. Advantages of Urban planning

10. Natural gas boilers

Green boilers consume as little fuel as possible or use renewable energy. Natural gas, though it is also a fossil fuel, has the particularity that it emits almost no toxic gases such as nitrogen oxides, particles, carbon monoxides nor Sulphur. It releases more water vapor and less carbon dioxide. It is the most environmentally friendly fossil fuel in terms of emissions, with 204 grams of CO2 per thermal kW/h. Therefore, natural gas boilers tend to be condensed, which means that they recover the heat from the water vapor coming out of the chimney, achieving higher thermal yields with less air pollution.

There are many technological advances for industries & households nowadays, but still much remains to be done in the field of implementing measures to reduce pollution & waste worldwide.

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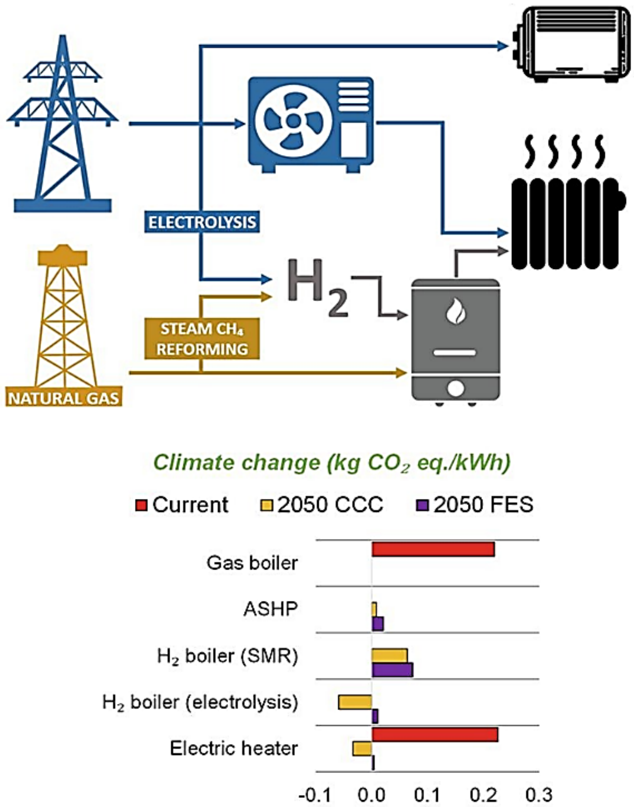

Fig. 14. Gas utilization and climates change

IV. CONCLUSION

Technological change brought about by green technology is relevant for both developed and developing countries. According to the WEF (2013), "so far, economists have devoted most of their efforts to trying to understand the way economic growth impacts the quality of the environment or income distribution within a country and vice versa. However, little is known about how these aspects of sustainability relate to competitiveness and productivity." In the past, they were associated with additional costs and burdens. There is increasing evidence, however, that green technologies offer numerous opportunities to develop new industries, particularly for countries whose industries are still developing. The worldwide demand for green technologies will inevitably increase due to the rising pressure on the environment. Countries will only be able to take full advantage of economic growth if environmental sustainability is ensured.

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