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Towards Sustainable Development: A Review of Green Technologies

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In recent years, climatic changes, global warming, energy depletion and other environment-related concerns have led to the emergence of green technologies. Researchers believe that the increase in the level of sustainable development will result in sustainable economics and societies. It will also have a very positive impact on sustainability in the future. Technical advancements in the modern society mark human creativeness and innovations. However, those technologies have resulted in the disruption of ecology from local to global level. Green technologies have a promising future in meeting the needs of economic sustainability. But, environmental and social sustainability factors need to be reinforced in a mutual manner. Both environmental and economic impact and efficiency of a technology should be analyzed before the implementation of technologies. It should be a win-win situation when economic and sustainable growths are highly emphasized. This paper reviews green technologies and discusses the challenges faced in advancing and implementing green technologies and trends that lead to sustainability. The paper also delineates regulatory policies and finance-related issues.

Keywords: Green Technologies; Clean Technologies; Sustainable Development; Sustainability; Review

Introduction

Green technologies are eco-friendly technologies that result in economic and social sustainability [1,2]. Green technologies may sound a sophisticated name, but it means no other than clean technology. In the earlier days, green technologies were known as environmental technologies [3]. From Information System perspectives, green technologies encompass environmentally friendly products that reduce the production of Greenhouses Gases (GHGs). They have in the past been viewed as a costly alternative to cheaper, unsustainable technology which has been in use all through.

Sustainability through green technologies means coming up with nature-friendly or eco-friendly technologies that not only meet human needs but at the same time minimize waste generation and support life today and in future [4,5]. Therefore, sustainable development must be met in all the three dimensions, i.e., social, economic and environment [6,7]. In this paper, we provide an overview of green technologies. The challenges faced in advancing and implementing green technologies and current trends that lead to sustainability are discussed. This paper also delineates regulatory policies and finance-related issues.

The rest of paper is organized as follows. The 'Review of Green Technologies' section explores application areas of green technologies. Next, in 'Challenges faced by Green Technologies' section, we discuss issues faced in advancing and implementing

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green technologies. Further, the potential benefits of green technologies are delineated in 'Opportunities for Green Technology Markets' section. Finally, the study conclusions, author perspectives, and future research directions have been provided in 'Conclusions' section.

Review of Green Technologies

This section provides an overview of thirteen application areas of green technologies where they have been implemented successfully. Systematic and best evidence reviews have a methods section. This section enables motivated researches to repeat the review. Narrative reviews do not have a methods section but should include some information about applied methods at the end of the introduction.

Water Treatment

Water is an essential element in life. In our world, several regions suffer from water contamination and scarcity. Water treatment is the act of removing undesirable contaminants from water. Undesirable substances may include biological, chemicals and even physical pollutants making it viable to be used in other applications. Water treatment is the solution preferred by many developing countries to reduce water stress. This solution may be focused on different perspectives depending on applications such as industrial and human activity [8].

Stages of water treatment

Today, the most common methods of water treatment include coagulation and flocculation, sedimentation, filtration, and disinfection (Figure 1).

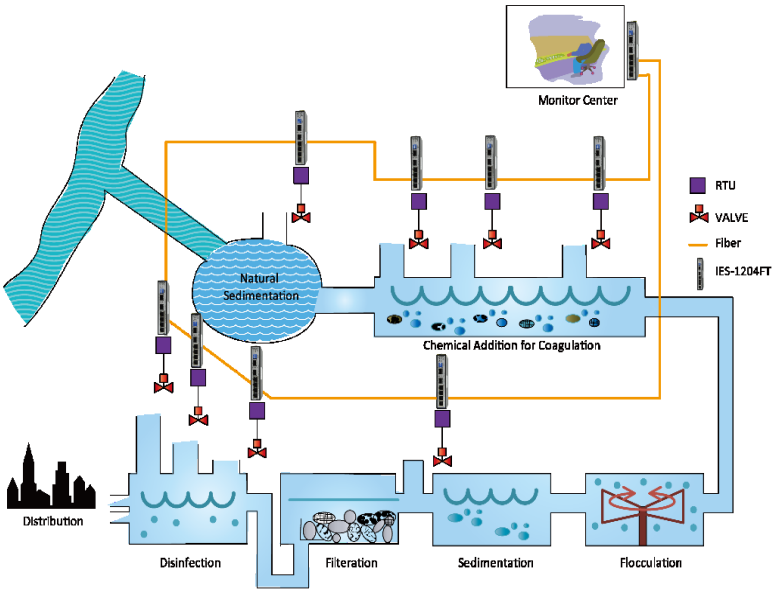

Figure 1. Basic model of water treatment scheme.

Coagulation and flocculation in most cases are often the first steps in water treatment. During this stage, a chemical with a positive charge is added to the water and the negative charge is attached to the dirt. This process detaches foreign proteins from water that form large particles called Floc [9]. Those large particles are then removed through sedimentation. The filters trap small particles that escape in the filtration stage. With current green technologies being implemented in water treatment process, most water treatment plants use advanced filtering systems such as Nano filters and membrane filters [7,10]. These filters trap minute particles [11].

The last stage is disinfection. The step removes biological organisms such as parasites, bacteria, viruses, and protozoa [9]. In the modern treatment plants, the commonly available disinfectants are chlorine and chlorimide. However, this method has proven to cause a carcinogenic effect. Thus, Ozonating is a process that is being encompassed by many developing countries [7].

Safe water is required to sustain life. Since clean water cannot be determined by physical examination only, chemical tests are done to determine its standard. The essential elements must be available and in the right quality [6]. The World Health Organization (WHO) and the United States Environmental Protection Agency regulate the quality of the water. After treatment, water is not piped to the households and industries, but the qualitative tests are done until the water meets the standard required by those bodies. These agencies have set regulatory policies that state the number of contaminants that can be found in the water of any specific area [12]. Every water treatment system must meet those Safe Drinking Water Act standards.

The WHO is laying out regulatory laws almost every year. In 2005, it was estimated that around 94% of the diarrhea cases reported could have been reduced by treating water for consumption [7]. The remedy was to use green technologies such as chlorination, safe can storage, filtration and solar treatment. Such a sustainability of water has been achieved in many countries [1,10,11].

Sewerage Treatment

This section portrays technology advancements at present that bring sustainable wastewater treatments.

Wastewater treatment can be termed as the process of removing solids, organics, and nutrients from the effluents of households and businesses. The knowledge of the sewerage treatment has evolved from early centuries. In the modern society, green technologies have been encompassed in this field to help removing physical, biological and chemical contaminants from the effluents to make them eco-friendly [11]. Wastewater treatment has a significance in that it allows the water from the industries to be treated before being discharged back to the environment [8,9]. It is believed that the wastewater contains harmful compounds that will not only interfere with the quality of the environment but have adverse human health complications [3,5]. While designing a wastewater treatment plant, the following factors are put into the consideration [7]:

- remove organic and biodegradable materials
- extract the part that is solid
- get rid of pathogenic microbes

A systematic modeling of the treatment plant is shown in Figure 2 on next page. Wastewater primarily occurs in four stages: screening, primary treatment, secondary treatment, and final treatment

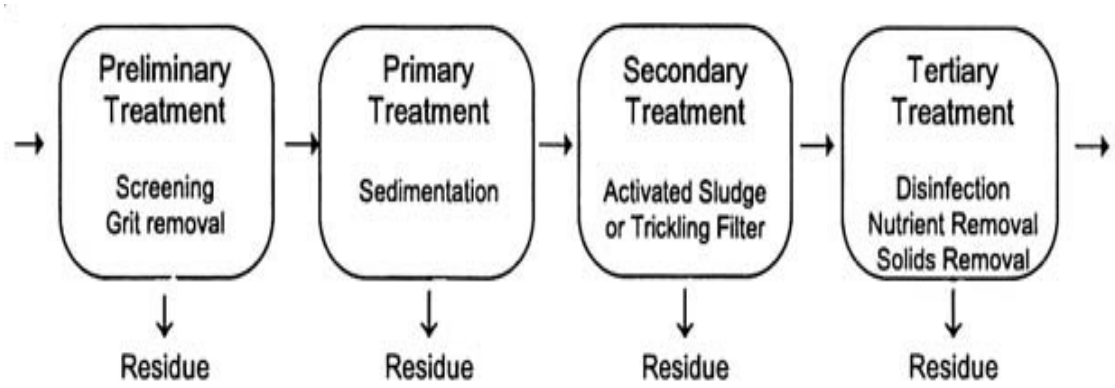

Figure 2. Common steps involved in wastewater treatment

Screening is the first stage of wastewater treatment. It removes large solids and objects from wastewaters. The primary steps separate the organic part of the waste through sedimentation tanks where they sink and settle into the ground. The effluent that leaves the main treatment contains high levels of Biochemical Oxygen Demand. Thus, secondary treatment proceeds to break down the organic matter using biological processes [6]. Wastewater contains a numerous number of nutrients. The final stage reduces the level of nutrients before discharging the wastewater into the rivers [5].

Eutrophication is one of the adverse effects that leads to environmental degradation. The growth of plants in the water affects the level of oxygen and carbon dioxide in the water causing the death of the aquatic animals [9].

The increasing level of environmental awareness has led to various industries and homesteads to deploy green technology techniques for reusability of wastewater [9,13]. The regulatory rules set by the government and environment conservative bodies force the industry to seek technologies that minimize wastewater being produced and ensure recycling [3].

Green technologies have ensured that the wastewater produced by the industry and homesteads can be used in other areas such as irrigation and livestock watering in arid and semi-arid areas after the treatment [11]. As manufacturing industries are being designed, many have found the importance of creating a recycling plant within the same plant to cut on the cost of wastewater management [6,10]. The final water effluent may be reused in the manufacturing process. The consensus is that it is easier to treat wastewater than to formulate new plans for obtaining fresh water from underground sources [5].

The technology advancements such as the use of Microbial Fuel Cells have a promising future in sustainable wastewater management [8,13]. Though technology has aroused some hitches in the universal application and economic viability of the project, further research is ongoing on how to make the technology the part of the future prototypes of the sustainable wastewater treatment [4,7,13].

Solid Waste Treatment and Management

Solid waste is one of the major aspects of sustainability that has been focused in the recent past [1,14]. The government-supported solid waste management schemes have resulted in the creation of innovative technologies that reduce waste generation [5,15].

In accordance with Product Stewardship Bill 2011 of Australia [16], there is an urge for every business to maintain responsibility and keep the environment free from hazardous waste. These regulations and codes played a pivotal role in economic and social development sustainability [1,2]. The waste disposals into the landfills go against sustainable development. The guidelines for a sustainable development are designed to cover six steps as shown in Figure 3 below, *i.e.*, Reduce, Reuse, Recycle, Recover, Incinerate and Landfill [5]. Disposing waste into landfills goes against the principles and means that new products will be processed from scratch. The end results are that there will be an increase in the demand for fuel, energy and other resources. Also, as the waste breaks into these landfills, the production of GHG emissions such as carbon dioxide and methane increases [17,18]. The technology used in waste management differ in developing and developed countries, rural to urban areas, and residential to industrial zones [8,15].

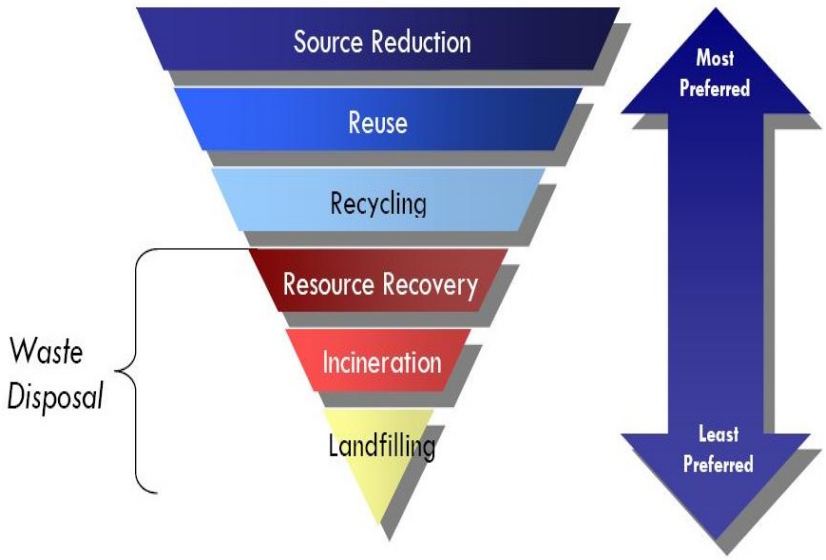

Figure 3. Solid waste management hierarchy.

The old technologies adopted by waste recovery industries saw the waste disposed of in the landfill's compost to form fertilizers. However, the latest green innovations have led to the development of aerobic digesters such as bioreactors that encompass in-vessel treatment of waste [15]. The new advancements in technologies not only does it manage waste but act as a source of renewable energy. Other waste management includes gasification and plasma synthesis, and zero waste programs [19].

Air Purification

Air pollution is largely becoming a technical issue. Air pollution is the introduction of harmful chemicals and GHGs into the air. They result in human and animal diseases and

end results are a damage to the atmosphere [11,17]. Air pollution is believed to be because of human struggle to achieve development. The common pollutants are industries and transportation devices. Various gasses such as sulfur dioxide, nitric oxide, carbon monoxide and more toxic gasses are emitted in large amounts. Air pollution has become an escalating factor after the GHGs have led the depletion of the Ozone layer [9].

Air filtration using green technologies has been encouraged in most industries. Most of the companies reduce air pollution by filtering GHGs during the emission process [18]. An example of technologies to reduce air pollution includes lead-free fuel and the introduction of catalytic converters. The introduction of such green technologies to trucks, buses and small vehicles will lead to significant reduction of air pollutants [11].

In the modern world, more fuel-efficient vehicles and hybrid electric cars have seen the reduction of air pollutants. These cars saw the reduction of gasoline intake by 50%. The technologies which have largely been implemented in most cities have seen air pollution reduction in the urban sector [7,8]. In power plant productions and industrial areas, filters in the emission chimneys have reduced gas pollution. Although no current technology has been put in place to deal with GHGs such as carbon dioxide, many industries have found a way to reuse gasses such as anaerobic bioreactors [20].

Environmental Remediation

Environmental remediation is an important focus of the green technologies aimed at maintaining sustainability [2,14]. This section focuses on green technologies that aid in the treatment of waste, help in the reuse, eliminate or reduce hazardous waste from the environment [5]. Environmental remediation knowledge has been evolving since the 20th century. Environmental remediation can be termed as the removal of pollutants or other contaminants from soil and waters. These pollutants can accumulate in living organisms and result to carcinogenic effects and other toxicity. In some cases, remediation actions can be because of a regulatory requirement, after assessment of human health and overall economic conditions of the environment [3].

Energy Conservation

Energy conservation refers to the effective production of energy that meets current needs without compromising on future availability [4]. Green technologies have brought a motivation to innovate new sources of energy including renewable sources while that replace fossil fuels. The energy crisis has never been an issue with green technologies. In fact, they have led to the introduction of devices that require minimum energy. In other words, energy conservation can be termed as energy efficiency and is a major pillar of sustainable development [11].

Energy conservation will see an increase in economics, financial and social security. Improved energy efficiency in homesteads, businesses, and transportation is expected to reduce energy demands by 2050s [21]. The green technologies have proven to be useful in some countries as it has slowed the rate of import and relying on the energy produced domestically.

Renewable Energy

Energy has become a vital factor in economic growth and social development of any country. With rapid power consumption becoming a global challenge, the need to find alternative and energy efficient technologies have been put in place. Fossil fuels are used as a source of energy for centuries. In definition, fossil fuel is a substance where solar

power is obtained, turned into chemical energy and stored in plants and animals who have been dead for decades [7]. When plants are acted on to produce energy, they emit GHGs. The GHGs result in adverse effects on the environment and future generation [3,17].

From a research study conducted in Malaysia in 2002 [18], fossil fuels are recorded as the primary source of electricity generation as shown in Table 1 below.

Table 1. Emission Factors of Fossil Fuels for Electricity Generation [18].

	Emission Factor (kg/kWh)			
Fuels	Carbon Dioxide	Sulphur Dioxide	Nitrogen Oxide	Carbon Monoxide
Coal	1.1800	0.019	0.0052	0.0002
Petroleum	0.8500	0.0164	0.0025	0.0002
Gas	0.5300	0.0005	0.0009	0.0005

Renewable energy sources (such as hydro, solar, geothermal and biomass) are of great significance to economic and environmental sustainability [1,2]. These clean technologies can lead to the production of large kWh with less emission of GHGs [11,17]. The International Energy Agency confirms that over 50% of electricity energy by 2050 will come from renewable energy sources [21]. However, a long-term grid is required to achieve sustainable renewable energy [22].

Capture and Storage Technology

Capture and Storage (CCS) is aimed at reducing GHGs emission. CCS captures carbon dioxide from environment and stores it in a viable surface. It follows a 3-step process as explained in Figure 4 below. The process involves capturing carbon dioxide from power plants, transporting carbon dioxide through pipes and the storage of carbon dioxide [23]. CCS technology sees carbon dioxide deposited in oil and gas recovery sites or un-mine-able coal sites.

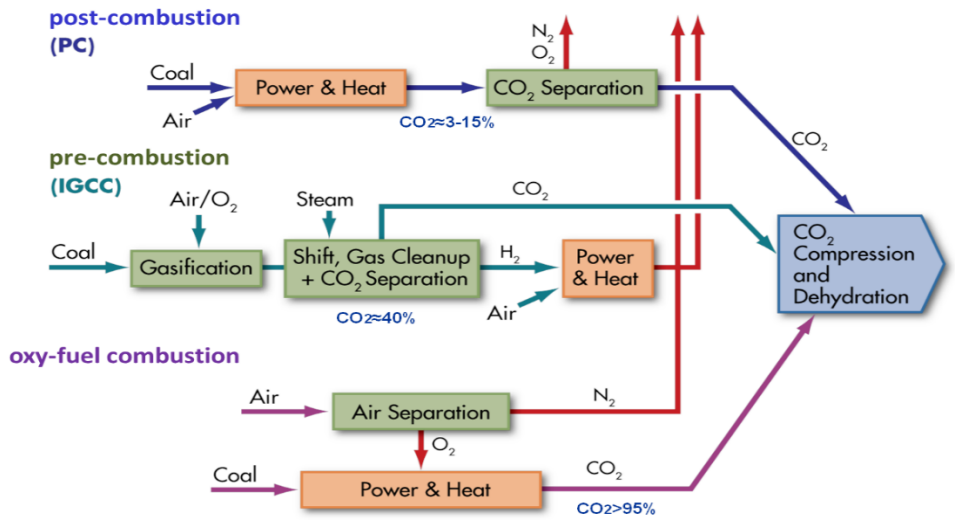

Figure 4. Summary of Carbon Dioxide Capture Technologies [17].

Though CCS technology seems to bring about sustainability, it has only been partially integrated on a commercial scale [1,17].

Green Building Practices

Conventional buildings are the number one contributors of GHGs. However, this sector has focused on coming up with green buildings [24,25]. In the wake of climatic changes such as global warming, Green Building Practices (GBPs) are receiving global acceptance [7,9]. The GBPs are environmentally friendly and more economically reliable. Industries have come up with a new technology of building houses that are eco- and nature-friendly.

The GBPs is a new technology in both developing and least developed countries. The research to determine how GBPs contribute to environmental sustainability is still substantial [1,2,11]. However, since they are economically productive, the countries especially the least developed countries have embraced the technology as a sustainable development [19].

Green buildings generally cost 2-7% more than the normal conventional buildings regarding the capital. The difference in money can be suggested to arise from modeling and designing cost. Green technologies require a sophisticated design which is costly. The rise of capital could also be because of green materials and green technologies used in the project [24]. Even though green buildings are costly, there are economic productivities that result from GBPs. As noted earlier, green technologies are eco-friendly, have more property values, are more energy-efficient and above all, they are energy efficient [24].

The impact of green buildings on the environment and social life [3,15,24,25] is attained by:

- efficient and efficient use of resources such as energy and water
- minimization of waste, water and reduction in environmental degradation
- providing occupation to employees, thus improving health and overall productivity

Sustainable Transportation

Sustainable transportation is a transport system that results in a positive impact on the environment. With current green technology being utilized in the manufacture of green vehicles, there will be less emission of GHGs compared to standard cars, thus leading to a sustainable environment [7,11]. Environment Protection Agency defines sustainable transport system as [26]:

- a transport system that allows society to quickly fulfill the urge or development at the individual level, company or even community level sustaining social-economic and environmental health
- a transport system that is efficient and supports the competitive economy and may result in economic advancement
- a sustainable system that reduces GHGs emission by utilizing a renewable source of energy and has reduced impact on a waste generation.

The introduction of electric hybrid cars leads to a reduction in carbon dioxide emitted during transport. The structure of hybrid cars is an internally designed combustion

engine with an electrical engine that helps in achieving sustainable transportation system [23].

Clean Industries

Clean industry is a term referred to industries that minimize environmental degradation. Clean industries encompass green technologies in the manufacture of products and in the long run activities that result in sustainability [1,2]. The term clean industry is used interchangeably with green industry and may also refer to the companies that function to solve environmental challenges [3].

It's hard to say the size of the distribution of green technologies worldwide as different countries are in a race to see who's winning the clean energy race [11]. For example, a report analyzed by Pew Charitable Trusts demonstrated that China's $34.6 billion budget is leading in clean technology followed by United States' $18.6 billion budget [27]. Also, there are policy laws that have contributed to the increase in efficient production of clean products.

Hydrogen and Fuel Cells

Hydrogen is a very rare element in the universe. Hydrogen can be extracted from different sources such as coal, crude oil, natural gas, and water. But, water is the only source known to be pollution free [6,28]. With modern technologies, internal combustion engines in most cars can be modified to run on arrays of fuels including hydrogen fuels. Vehicles that use hydrogen cell fuels are three times more efficient than those that burn gassed fuels in their engines [13,28,29].

The first hydrogen fuel was discovered by William Robert Grove, a Welsh physicist, in 1842 [30]. Later, NASA used fuel cells to launch its shuttle into a space mission. Hydrogen and Fuel cells have transformed industrial and social fabrics of most countries worldwide [13,31]. Today, many people believe that fuel cell technology will have a significant impact on a new technological renaissance. These innovations are expected to be environmentally friendly and will positively impact economy [31]. William Clay Ford Jr. (Executive Chairman, Ford Motor Company) said, "In today's world, solving environmental problems is an investment, not an expense". The significant features that make hydrogen cells more preferred over conventional fuel are that they have no emission, and they are quiet and free from vibration [13,28].

Agricultural Technology

Conventional agricultural technologies take a toll on the environment. There is the emission of GHGs, pollution of waterways and utilization of tangible resources [18]. Clean agricultural technologies range from drip irrigation to reduced water usage and from machinery farming to natural pesticides. Investment in agricultural sectors is likely to be influenced by cost-effectiveness, consumer demands, regulatory mandatory and public interest [17,29].

The green technologies are being used to improve the efficiency of crop planting and harvesting, use of chemicals for managing pests and weeds, making of fertilizers for covering water pollution and mitigating soil erosions [11]. Research institutes are investigating eco-farming practices for reducing the emission of methane, replenish soil carbon made and replace fossil fuels with fuel made from plant biomass [18].

Challenges Faced by Green Technologies

Technologies have impacted our society and its environment in many ways and helped in developing more advanced economies such as today's global economy [31]. Green technologies are environment healing technologies. They minimize environmental damages brought by technologies created by humans for their conveniences [8]. However, green technologies have been facing challenges that make it harder to realize their set goals. Such challenges include marketing challenges, economies of scales, financing problems, and regulatory and technical challenges [9]. Below we discuss major challenges faced today in implementing green technology initiatives, design and manufacture.

Development Challenges

Green technologies have experienced unreliability and disruption of fuel resource supplies. They make it difficult to have a lasting fuel contract as many small renewable energy programs lack palm oil plantations and mills [10]. Interconnections between other electricity providers and green technologies are not high enough to enable them to access energy supplies provided by renewable materials. The use of renewables has been limited by the price point. The renewable energy materials are costlier than available fossil fuel energy sources. Besides, natural gas availability presents a significant competition to the development of green technology advances [29].

Examining the effects and implications of national policy in making recommendations for appropriate technology extension has been a challenge. There are no sufficient advancements to examine these implications. This has delayed green technology development programs since some of the national policy influences are not well known [11].

Market Challenges

Expanding the occupation of green technologies in developing countries is most disadvantaged by the hurdles encountered during the trade development. There is inadequate knowledge about worldwide available environment-friendly technologies and the associated services in the market. This insufficient worldwide know-how about green technology suppliers slows down the manufacture of nature-friendly green products. Also, there are environmental and industrial concerns and views incorporated in devising of international policies on environment and trade.

The complex regulations of entering world's green technology markets keep out small and medium-sized businesses. Additionally, on the supply chain side of marketing a new product, it takes the consumers a lot of time to switch from old products to the new ones. This process can be challenging and long [10]. The green chemistry products have faced resistance and barriers to full acceptance. There is a lack of agreement on products to be considered safer for human use [8,11,32].

Technology Challenges

The world lacks adequate professionals with skills and knowledge matches green technologies and the values it stands for. For instance, in green buildings, professionals do not appreciate all components of green buildings. These include ventilation, temperature, and lighting control as well as efficient methods of obtaining energy that minimizes environmental damages [3,9,24].

As green technologies keep advancing, it must keep up with the latest technologies to meet demands to outgrow previous ways of handling their businesses. For effective communication across multiple countries, green technologies need real-time methods to access their data. Advancements in Information and Communication Technologies is a challenge that green technologies must continuously innovate for them to thrive and achieve their set goals [25].

Financing Challenges

Financing renewable energy projects have been a significant challenge. To fund renewable energy projects the small renewable energy project developers must have a firm financial standing. And they should be financially capable of doing so through equity injection rather than depending mostly on commercial loans. The developers lack adequate funds to finance their projects hence they start to stagnate. The Government should consider giving out a soft loan to sponsor renewable energy projects as national projects.

In agriculture field, green technologies have encountered challenges of identifying suitable technologies for generating income through sustainable agriculture, like rural renewable energy and ecological agriculture [9].

Regulatory Challenges

Managing global regulatory compliances regarding green technologies are a hurdle that slows down the development of green technologies. While massive investments are taking place within the US, there are extensive opportunities for renewable energy projects in other countries [19]. Getting those countries to comply with green technology regulations has proved impossible.

Organizations driven by green technology projects face challenges of identifying, meeting and managing regulations which vary widely from country to country [9]. Complex rules and regulations of entry into the green technology global markets make it difficult for medium-sized and small enterprises to penetrate the market via green technologies [2]. The effectiveness in implementing energy regulations differs significantly from one country to another. Some countries lack enforcement of government regulations to thrust ahead of green technology initiatives. For example, in Asia, there are no regulations on green building creativities. Some countries have green building agenda, but not all are supplemented with proper incentives or rules to spur growth [19,24].

Opportunities for Green Technology Markets

Green technologies consist of complicated and expensive but simplest technology advancements. They serve basic human needs and can explore new possibilities of exploring and improving comfort and leisure in human lives [8]. Green technologies offer new and interesting opportunities in the construction and development of extra durable, energy efficient materials to provide a reliable energy source [8,11]. New eco-friendly products and services can be created aiming at increasing growth rate while using minimum resources and causing minimum damage to the environment [3].

Reducing the number of resources used in developing green products would significantly reduce adverse impacts, hence avoiding economic and environmental collapse. Green technology market has identified renewable energy, water recycling and treatment services, the most substantial factors for export opportunities and growth. Green

technologies have a chance to open a competitive, powerful green technology sector in developing countries. This can be vital in spreading and extending green technology advancements and help minimize damages created by industrial growth [9].

CONCLUSIONS

The understanding of green technology challenges is making related technology sustainable and competitive. The green technology innovations solve or minimize problems especially in agricultural and manufacture sector.

We can overcome most of these problems through slowing down green technology developments if necessary steps are considered. For instance, the governments should offer to fund renewable energy projects when the owner is stuck because of the financial constraints. Or the government should put in place targeted financial enticements. They may include lowering local government taxes to encourage the import of renewable materials for energy and promoting adoption of green buildings in the market [2,24]. Moreover, removing fossil fuel subsidies would strengthen economic incentives for green technology advances. Educating public and training personnel dealing with green technology advances can provide the necessary knowledge required for technologies to work efficiently. If humans can manage to overcome challenges encountered by green technologies, it can have many beneficial purposes such as waste management, incineration through recycling, water and air purification and use of energy conserving devices. They will give people the comfort they need to live their lives comfortably.

From the above details, we can conclude that green technologies are a must in today's world. Since conventional technology is challenging sustainability, green technologies should be carried out to ensure sustainability of the eco-social environment. Though there are some shortcomings in the implementation of clean technology, but, if we see its long-term benefits, we and our future generations will surely benefit [4]. Also, technology will help us conserve our limited sources. Thus, the easiest way to maintain economic, environmental and social sustainability is education.

CONFLICTS OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this paper.

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