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Review

Sustainable Development Perspectives of Solar Energy Technologies with Focus on Solar Photovoltaic—A Review

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Abstract: This study examines the sources of energy related carbon dioxide (CO_2) emissions, the hazards of climate change and greenhouse gas (GHG) emissions, the global solar energy potential, renewable energy sustainability indicators, impediments, and the environmental implications of fossil fuels. The purpose of this study is to investigate viewpoints on solar energy technologies for sustainable development, with a particular emphasis on photovoltaic (PV), as well as the literature on solar energy technology performance, in order to ascertain worldwide solar energy adoption trends. The discussions address the solar industry's fundamental ideas, the global energy scenario, the highlights of research conducted to improve the solar industry, prospective applications and future challenges for a more efficient solar industry that may help alleviate the energy crisis. A review of the framework and development of Renewable Energy Sources (RES) and Renewable Energy Laws (REL) on a global scale was conducted.

Keywords: sustainable development; green building; renewable energy; energy efficiency; solar energy; solar energy technologies; solar photovoltaic

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1. Introduction

The world is fast progressing toward a global agenda guided by the Sustainable Development Goals (SDGs). According to a study conducted by M. Stafford-Smith et al. (2016), nations convened in September 2015 in New York for the United Nations 2015 (UN2015) to commit to the Sustainable Development Goals (SDGs), which must be achieved by 2030. The Sustainable Development Goals (SDGs) were adopted by world leaders in New York at the United Nations. These 17 goals and 169 targets provide a strategy for all nations' long-term development, focusing on economic growth, social inclusion, and environmental conservation. The focus has shifted away from agreeing on goals, and toward implementing and eventually attaining them. The world has concentrated rightly on achieving an integrated agenda through the SDGs, however inadequately accomplished in this initial iteration of such a transformative agenda [1]. By and large, fulfilling the SDGs' targets would require a flexible and integrated global innovation system that actively connects regions throughout the world, connects research and society actors, and allows co-production, and transfer of locally relevant knowledge and technology. As a result, our endeavor has concentrated on integrating the substantive goals.

These objectives imply a path toward sustainable growth, which has led in the concept of green buildings developing as a new trend in the built environment's innovative technology sector. Green buildings, as defined by these writers, Z. Ding et al. (2018), are those that benefit the environment. Promoting and implementing green building practices has thus become a central element of contemporary construction, as it is thought to promote healthy, safe, comfortable, and ecologically friendly structures. The United States Environmental Protection Agency defined green construction, also known as sustainable building, as both a structure and the application of ecologically responsible and resource-efficient strategies throughout the life of a building [2]. As a result of variances in economic growth, geographical environment, resource availability, and other factors, there is no reciprocal definition of green buildings in the literature.

According to Khan et al. (2019), the evolution of green building from sustainable development has been a laborious process that has resulted in the establishment of green buildings in a variety of domains. Additionally, green buildings contribute significantly to the infrastructure development of countries and regions, with an emphasis on sustainable building management from the design and construction stages through operation and maintenance called building's life cycle. Green building rating tools are a collection of instruments for assessing the performance of green buildings. Green buildings are those that pass the examination, proving sustainable construction and a superior quality of life [3]. Thus, the overarching goal is to mitigate resource depletion, climatic impacts, and building-related emissions.

The Notebook Planning Commission (2018) noted that buildings consume energy, water, raw materials, and generate trash, in addition to emitting potentially dangerous atmospheric emissions throughout their construction, occupation, maintenance, renovation and demolition. These facts led the establishment of green building standards, certifications, and rating systems aimed at decreasing buildings' environmental effect through sustainable green building design. The Building Research Establishment's Environmental Assessment Method (BREEAM), the United Kingdom's first green building grading system, bolstered the 1990s movement toward sustainable design [4]. From this point forward, other green building rating tools, such as the Leadership in Environmental and Energy Design Leadership (LEED) and Green Star, were established. BREEAM is currently regarded as the most powerful rating system. Furthermore, these rating methods assess green buildings while taking into account a variety of parameters. Green rating systems frequently focus on criteria such as interior environment quality, energy and material [2]. Thus, the green building and sustainable construction movements of the last decade have prompted a thorough examination of building materials and practices all over the world.

Additionally, infrastructure investments also have social and environmental consequences, increasing vulnerability to natural disasters and leaving behind an unsustainable debt burden. Regardless, a study conducted by S. Thacker et al. (2019) recommended that governments and politicians build long-term visions for sustainable national infrastructure systems, as well as flexible strategies to demonstrate their vision [5]. Similarly, N.K. Sharma's (2020) research studied how infrastructure systems serve as the backbone of every society by delivering essential services, such as water, energy, waste management, telecommunications and transportation [6]. Therefore, sustainability and green building should thus begin with the selection and utilization of eco accommodating materials with related or preferred high-lights over conventional structure materials.

Moreover, according to L.F. Cabeza, A. de Gracia, and A.L. Pisello (2018), buildings account for over one-third of global final energy use and are a significant source of carbon dioxide ($_2$) emissions. Currently, it is estimated that space heating and cooling, as well as hot water production, account for roughly half of global energy consumption in buildings. Because space and water heating are dominated by fossil fuels, and cooling demand is expanding rapidly in nations with very carbon intensive power grids, these end-uses represent considerable potential to cut energy consumption, improve energy security and reduce CO_2 emissions. Building heating and cooling systems with low or zero carbon footprints and high energy efficiency have the potential to cut CO_2 emissions by 2050. The majority of these technologies, such as solar thermal, combined heat and power (CHP), heat pumps, and thermal energy storage, are already commercially accessible [7]. Despite the potential of these technologies, various impediments to market adoption exist, including greater initial costs, market risks for new technologies, incomplete information, and uncertainty, such as technical, regulatory and policy. In fact, the requirement to achieve energy efficiency standards in both new and existing buildings has prompted both research and design practices focused on decreasing CO_2 emissions and increasing indoor comfort and functionality.

Renewable energy was available in rural areas in the form of wind farms, solar plants, biomass plants and others. In urban contexts, particularly with the use of solar energy technologies called solar energy systems in buildings, such as solar thermal and photovoltaic (PV). Some other studies by N. Sánchez-Pantoja, R. Vidal, and M. Carmen (2021) also highlighted in the early years, research into the utilization of solar energy in buildings was highly technical. The focus of attention was on optimizing the installation in terms of energy efficiency and economic costs. The challenge of establishing energy models was based only on renewable energy systems. Furthermore, programs focused on promoting the installation of renewable energies on an urban scale, as well as storage energy systems, are critical to effectively combating climate change, improving global energy performance in cities, and achieving more resilient cities. In this sense, terminology such as "sustainable communities", "energy autonomy", or "energy self-sufficiency" were already being used to talk about sustainable development as a whole, incorporating the technical, environment, social, economic and political challenges [8].

According to M.H. Shubbak's (2019) research, the development of material components, production processes, and applications for both photovoltaic (PV) and Balance of System Technologies (BoS) is a significant research field in the modern day. The components of the BoS are critical for connecting, chemically protecting, and mechanically mounting the cells into panels, as well as electronically regulating their output levels for use, storage in batteries, or feeding into the utility grid. Additionally, the system incorporates testing and monitoring operations, as well as portable solar-powered gadgets [9]. Thus, whether centralized utility-scale or distributed, PV systems are composed of two distinct groupings of elements for solar cells and BoS, such as PV panels, electronics, and energy storage.

On the territorial level, several EU countries, such as Switzerland, Sweden, Germany, Austria, and Denmark, developed a new approach to solar planning which show that it is possible to achieve optimal use of solar energy, preserving the heritage and architectural quality of a site. Moreover, solar energy was identified as one of Malaysia's most promising alternative energy sources and is gaining popularity as a result of the findings. As a result, solar energy developed green potential in Malaysia's energy industry through preserving the environment. This study is divided into the following sections: Sections 2 and 3 show a literature review of the barriers on the environmental, health, political, economic, and social aspects of solar energy technologies. These trends lead to sustainable development aspects using the Sustainability Model that the social (S), technical (T), economic (E), environmental (E) and policy (P) perspectives (STEEP) model is based on basic sustainability principles as discussed in Section 4. Then, Section 5 is about challenges to develop solar photovoltaic (PV) in a solar energy generation; followed by, in Section 6, detailing sustainability of the solar photovoltaic (PV) and comparison of the efficiency of solar PV to other renewable energy. Further, Section 7 is about framework and the advancement of Renewable Energy Source (RES). Finally, in Section 8, conclusions of this study are discussed.

2. Environment and Health Barriers to Solar Energy Technologies

2.1. Climate Change

Research conducted by J. Nowotny et al. (2018), the production of energy has a significant impact on climate change. At the moment, the world community's principal objective is to mitigate the adverse effects of climate change. A related critical objective is to examine ways to create energy in an environmentally sustainable manner. The process of photosynthesis, which resulted in the removal of carbon dioxide (CO_2) from the atmosphere over hundreds of millions of years, culminated in the formation of carbon-rich fossil formations. Combustion of these deposits on a large scale releases unsustainable amounts of CO_2 into the atmosphere, resulting in an amplified greenhouse effect and eventual climate change, with the potential for catastrophic alterations to the planet's ecosystems. The fundamental environmental risk is that human activity will pollute and contaminate water, air, and soil. If this occurs, people's access to safe drinking water, clean air, and food will be endangered [10]. As a result, it is becoming increasingly evident that mitigating human-caused climate change through the use of solar energy is important to protect the ecosystem.

Renewable energy technologies have the potential to make a significant contribution to global sustainable development by supplying clean energy, to address issues such as food insecurity, poverty, and climate change. According to A. Shahsavari et al. (2018), global climate policy's primary strategies are greenhouse gas (GHG) emission reduction and climate change mitigation. Increased use of renewable energy sources is a critical component of achieving these goals. Solar energy technologies, such as solar photovoltaic (PV), hold enormous promise for reducing energy-related emissions and thus contributing to climate change mitigation. If global average temperatures continue to rise by more than two degrees Celsius per year, it is predicted that natural disasters will become more frequent, with hotter and longer droughts, agricultural failure, and mass extinctions [11]. In fact, climate change affects natural ecosystems as well as numerous human–environment systems.

Moreover, J. Cronin (2018) analyzed that the climate change adaptation potential is discussed in a variety of ways. Climate change mitigation is highly dependent on a significant decarbonization of the energy system. Through long-term changes in climate parameters, variability, and extreme weather events, climate change has an effect on energy system components. As a result of climate change, cloud cover is anticipated to decrease in low-to-mid latitude regions. Importantly, climate change is projected to have a ripple impact throughout the energy sector [12]. M. A. Hannan et al. (2018) also point to how Malaysia is currently making a variety of steps as a signatory of the United Nations Framework Convention on Climate Change to adhere to the policy in order to address the challenges of reducing excessive reliance on fossil fuels, reducing carbon levels, and achieving sustainable national development. In Malaysia, climate change has an impact on our daily life and has the potential to reduce energy related environmental impacts, such as GHG emissions from energy usage per unit of GHG [13].

Besides, according to the Kuala Lumpur Climate Action Plan 2050 (2021), Kuala Lumpur City Hall (DBKL) is committed to making this Climate Action Plan a success, and it is confident in its implementation strategy to create a Kuala Lumpur that is climate resilient and carbon neutral for all by 2050 [14]. The development of the Kuala Lumpur Climate Action Plan 2050 (KLCAP2050) was undertaken to address and fulfil four main components as shown in Figure 1. Lastly, Sustainable Energy Development Authority (SEDA) Malaysia discussed grid-connected solar photovoltaic (PV) systems, as well as the design of GCPV systems that are appropriate for Malaysia's regional climate. SEDA (2020) also discussed Malaysian grid connection requirements and standards, as well as PV inverter systems and related equipment that are suitable for Malaysian climate [15]. The training institutions located in Shah Alam, Selangor Malaysia at Selangor Human Resource Development Center (SHRDC) and Photovoltaic Monitoring Centre (PVMC), Universiti Teknologi MARA (UiTM) are shown in Figure 2.

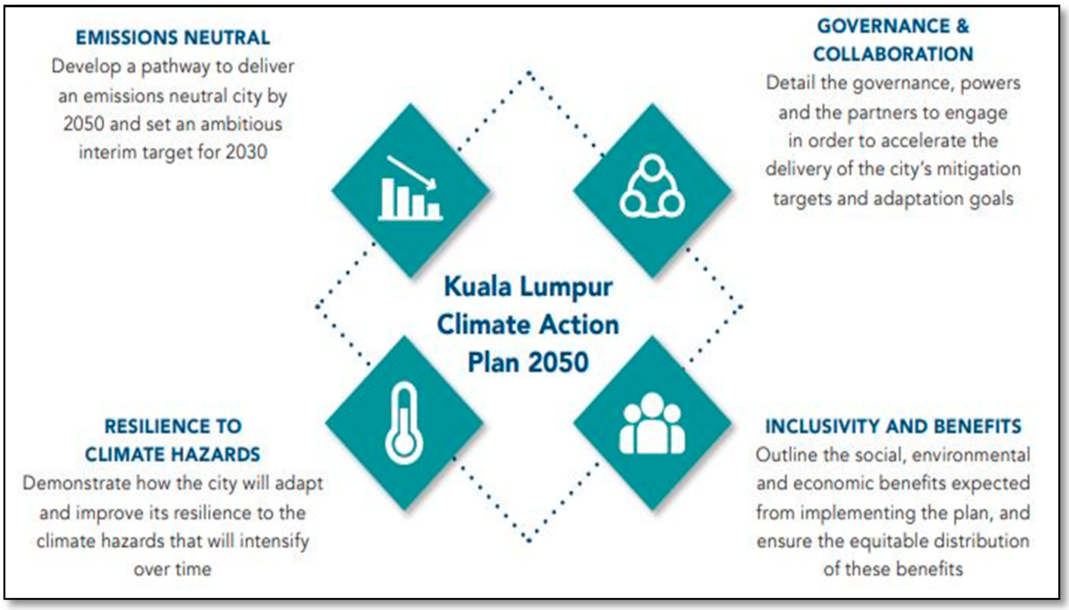

Figure 1. Key Components of the Kuala Lumpur Climate Action Plan 2050 [14].

Figure 2. Training institutions at Universiti Teknologi MARA (UiTM), Malaysia [15].

2.2. Greenhouse Gas (GHG) and Carbon Dioxide (CO_2) Emissions

The use of conventional fuels has resulted in a rapid increase in carbon dioxide (CO_2) emissions in the developing world, according to a study conducted by A. Shahsavari et al. (2018). Conventional energy generation is now the leading source of GHG emissions globally, particularly in developing countries, accounting for about 40 percent of global primary energy and approximately 40 percent of global electricity output. As a result, fossil fuel power plants emit massive amounts of harmful pollutants into the atmosphere, including carbon dioxide (CO_2), nitrogen oxides (NO_2), and sulfur dioxide (SO_2). CO_2 emissions growth in developing economies is primarily due to a significant increase in the use of conventional fuels, such as coal, oil, and natural gas, to meet rapidly growing energy demand [11]. Therefore, solar energy is the best solution to energy poverty, and it can provide excellent opportunities for reducing GHG emissions and indoor air pollution by replacing kerosene for lighting and firewood for cooking.

Global demand for energy produced by fossil fuels is a significant factor in the upward trend in GHG emissions and air pollution. According to S. Diwania et al. (2020), the solar PV has the advantages of increased efficiency and pollution free energy. Thus, solar PV installed capacity is increasing on a daily basis around the world [16]. Besides, research conducted by M.A. Hannan et al. (2018) into Malaysia's energy mix found natural gas and coal are the leading sources of GHG emissions, followed by hydropower. Oil reserves are depleting at an alarming rate, and it is no longer regarded a sustainable source of electricity generation. Malaysia is impacted by the hazardous emissions generated by fossil fuel combustion, which contributes to global warming. As a result, the use of fossil fuels is likely to contribute to the release of greenhouse gases (GHG) during their combustion, aggravating the climate change problem [13].

The majority of Ghana's rural villages, solar-powered systems and solar PV have been found by a study of A.A. Adenle (2019) to mitigate the carbon footprint of kerosene lights and firewood. According to an examination of survey data, South Africa uses solar energy technologies to reduce carbon emissions at a higher rate than Ghana and Kenya. Indeed, solar energy is a cost-effective method of generating electricity from solar radiation that has a minimal carbon footprint and causes no harm to the environment [17]. According to the survey conducted by M.R.M. Cruz et al. (2018), the European Union (EU) has set a target of reducing GHG emissions by 80–95 percent by 2050 relative to 1990 levels. This is only achievable with the combination of "green" energy technologies, primarily wind and solar. Wind and solar energy, in particular, are expected to provide half of the electricity in the EU by 2050. The demand for more "carbon-free" energy resources is increasing dramatically [18].

According to the Kuala Lumpur Climate Action Plan 2050 (2021), Kuala Lumpur's annual carbon footprint was estimated to be 25 million metric tons in 2017. Transportation accounted for the most emissions, accounting for 56 percent of total emissions in the city. The GHG Emissions Inventory is a critical tool for quantifying and estimating carbon emissions, as well as tracking, reporting and evaluating a city's progress on climate action. An updated inventory can notify Kuala Lumpur City Hall (DBKL), Malaysia, about the extent to which climate change mitigation initiatives and actions have resulted in actual GHG reductions or their equivalent in carbon emission reductions over time [14]. Meanwhile, without significant action by DBKL, it is estimated that Kuala Lumpur's carbon emissions will more than double to 2.3 times their 2017 levels by 2050, as presented in Figure 3.

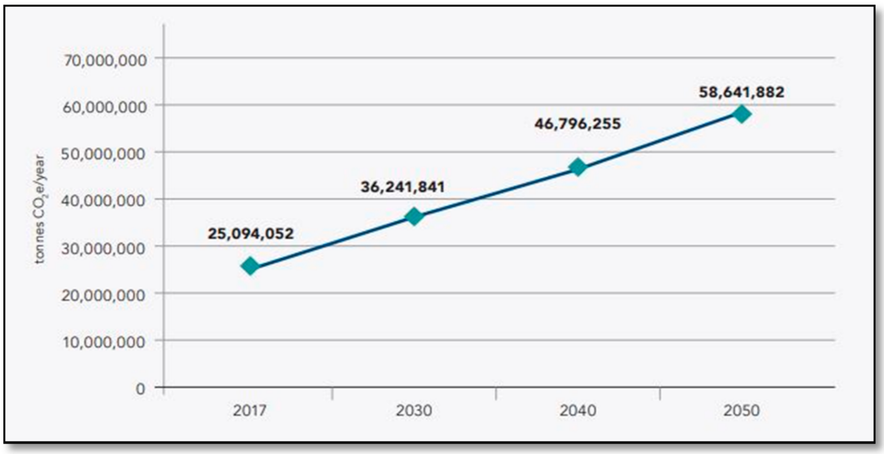

Figure 3. Emissions forecasts from 2017 up to 2050 undertaken by DBKL [14].

3. Political, Economic and Social Barriers to Solar Energy Technologies

H.S. Boudet (2019) discussed the economic, social, and political importance of energy, as well as the wide-ranging implications of energy choices on the environment and public health. This means that new technologies usually elicit intense public reactions. It is crucial to understand these public responses, and the elements that influence them because of public support, can have a significant impact on the adoption and deployment of new technology. These technologies include large-scale energy infrastructure projects, such as utility-scale wind and solar, fossil fuel and marine renewables, as well as small-scale 'consumer-facing' technologies, such as electric vehicles, rooftop solar, and smart meters.

As a result, this strategy identifies broad trends that can aid politicians, technologists, and the general public in communicating more effectively and facilitating the transition to a more sustainable energy system [19].

Energy is a vital component of economic growth and development. Renewable energy sources are necessary as energy consumption increases as a result of a growing population and developing economy. C.S. Durganjali et al. (2020) stated the amount of effort put into developing solar technology has increased significantly. The solar PV system's energy conversion efficiency and capital investment are very high. Moreover, to absorb adequate energy, a large number of PV cells are required. The effectiveness of the PV panel declines drastically when it overheats, thus requiring the installation of large quantities of solar panels [20]. Research by M.S. Rahman et al. (2017) discussed energy inputs; fossil fuels are used in a variety of production sectors. In Malaysia, minerals, such as tin, bauxite and iron, are consumed because they are used as raw materials in a variety of manufacturing processes [21]. Thus, distinct components of disaggregated energy consumption are analyzed to ascertain which have the biggest effect on Malaysia's economic growth

Research summarized by M. Irfan et al. (2019) also point to how the energy shortages not only have an impact on people's lives, but they also adversely affect the country's economic development. Solar energy projects require a significant investment and have limited economies of scale. It takes a long time for retribution. Several economic challenges occur, such as high initial expenses, to establish a new solar energy project, unawareness about market potential and limited government subsidies and banks' unwillingness to provide money for large projects. Besides, there are a number of social challenges, such as a lack of awareness about solar energy, particularly in rural areas, as well as a lack of social acceptance and participation. People continue to rely on traditional sources of electricity, which presents a significant challenge for new solar energy projects [22]. Meanwhile, research by G. Raina and S. Sinha (2019) stated utilizing solar PV technology to its full potential has been mostly unachievable due to a lack of public understanding about the technology. This is a significant barrier to the growth of solar photovoltaic systems, especially in underdeveloped nations. Lack of knowledge about the technology has been identified as a barrier to local customers recognizing solar PV as a viable choice. Additionally, land inadequacy is a concern, as huge expanses of land are necessary for the development of large-scale solar photovoltaic power facilities [23].

Besides, PV systems that become a part of the architecture itself due to aesthetic, technological and energy integration principles fall into the second category of interventions. In a recent study by A. A. Olajube et al. (2021), the projects with PV systems are divided into two categories based on the features of the ensemble "Building + PV system" after the intervention: Building Applied Photovoltaic (BAPV) and Building Integrated Photovoltaic (BIPV). Buildings in the first category have PV elements attached to the building envelope. As a result, they serve no other purpose but to generate energy. Traditional mono- and polycrystalline PV panels, as well as colored flat PV panels, were used in terms of PV technology. For home hot water production, hybrid panels or flexible modules were used in a few circumstances. Case studies were categorized based on common characteristics. The PV system's placement in relation to the historic structure, the position of the modules on the building, the type and amount of technological, aesthetic, and energy integration, and the PV technology utilized have all been divided into six categories. These categories synthesize the key approaches to PV integration from the award case studies and can be used to recommend best practices. Some of the groups' successful PV integration scenarios have been extended and discussed. Overall, PV modules provide several roles in addition to their core function of energy production, such as weather protection, thermal insulation, acoustic insulation, natural light control and safety, as well as becoming architecturally integrated into the building [24].

4. Sustainable Development Aspects Using the STEEP Model

The social (S), technical (T), economic €, environment€(E) and policy (P) perspectives (STEEP) model is based on basic sustainability principles, as well as the authors' field experience. According to these authors, D. Akinyele et al. (2018), sustainability is defined as the "perceived potential for a system or project to endure, build a self-perpetuating capacity within a community, and eventually reach the end of its pre-determined lifespan or evolve into another beneficial foam" in terms of distributed off-grid energy generation systems. This research summarizes solar PV, wind, biomass, small hydro, micro turbines, reciprocating internal combustion engines, and fuel cells, among other micro grid technologies, status, and applications. It then proposes the STEEP approach, which is based on enabling aspects, namely social (S), technical (T), economic (E), environmental (E), and policy (P) perspectives, to address the stated problem. This model is based on the basic idea of sustainability, the authors' actual experience, best practices, and background knowledge of the micro grid concept. The goal of the model is to provide insight into the approaches and actions that are required to achieve sustainable micro grids in remote communities.

The research employs rural communities in Nigeria, West Africa, as case studies to highlight the need for the STEEP strategy in micro grid planning and development. The study offers the STEEP-based sustainable planning framework (SPF), which can serve as a basic framework for designing micro grids in any distant site. As a result, the STEEP model can be thought of as a comprehensive approach to conceptualizing, assessing, planning, and regulating localized energy systems. The research shows that addressing a major challenge, such as system failure, without any of the five aspects of the STEEP model results in an incomplete solution. This is because all aspects must collaborate to overcome the barrier and accomplish the desired sustainable energy development, which goes beyond typical techno-economic planning perspectives, such as how lack of education influences people's energy consumption habits [25]. There is a lack of study of the STEEP model towards solar energy technologies, especially in solar PV. Hence, many are concerned that the STEEP model needs a deeper study which includes a study of PV in terms of social (S), technical (T), economic (E), environmental (E) and policy (P) perspectives, due of lack implementation of it in any country.

5. Challenges to Develop Solar PV in Solar Energy Generation

The development of innovative solar energy technology by E. Kabir et al. (2018) is one of several critical options for satisfying the world's growing energy needs. Rapid growth in the field of Solar PV faces several technological challenges, including low solar cell efficiencies, low performing balance of systems and institutional limitations, such as inadequate infrastructure and a lack of skilled workers. Besides, there are economic challenges, such as high upfront costs and a lack of financing mechanisms. Hence, the high initial investment cost of PV technologies frequently discourages developers from investing in solar PV technologies [26]. M.H. Shubbak (2019) found technological innovation alone will not suffice to address the serious concerns of climate change and fossil fuel depletion. Policymakers, economics, and social scientists all have a critical role to play. This function comprises developing and implementing effective renewable energy subsidization policies, conducting feasibility assessments on relevant projects, promoting technology acceptance, and adopting worldwide regulatory legislation. As a result of the worldwide nature of the repercussions of energy difficulties, their solutions must also be global in scope geographically, organizationally, and multidisciplinary [9].

Solar PV technology has advanced dramatically, as can be seen in research by G. Raina and S. Sinha (2019), in recent years, however it has yet to prove sufficient and requires further research. Solar PV technology's low conversion efficiency in comparison to conventional systems continues to be the most significant technological hurdle in the development of solar energy systems. Another constraint is the inability of photovoltaic plants to respond immediately to load demand. This problem does not occur in conventional power plants, which results in increased efficiency. Numerous studies also demonstrate a variety of additional technological challenges in the development of solar energy generation, including the intermittent nature of solar radiation, which impairs the PV system's ability to meet consumer demand, as well as differences between standard and real-time conditions, which affect performance. When a component fails, the solar photovoltaic system frequently becomes inoperable until the component is replaced [23].

6. Sustainability of Solar Photovoltaics (PV)

6.1. Solar PV Sustainable Development

Sustainable development needs the preservation of natural capital, of which the regulations provide for renewable natural capital. H.E. Daly (2017) discusses two clear concepts of sustainable development that apply to the management of renewable resources. At the beginning, harvest rates should equal regeneration rates, which is referred to as sustained yield. Natural capital must be understood as regenerative and assimilative capacities, and failure to maintain these capacities must be viewed as capital consumption, which is not sustainable. Natural and man-made capital can be maintained at a variety of levels. Second, waste emission rates should be proportional to the inherent assimilation capacity of the ecosystems into which wastes are released. Natural capital is complementary to artificial capital as a source of raw materials and energy. Apart from that, natural capital's capacity to absorb waste products complements the artificial capital that generates those wastes. In a nutshell, growth is the quantitative expansion of physical scale, whereas development is the qualitative expansion or unfolding of potentialities. Quantitative expansion in populations of both people and goods must eventually come to an end, but qualitative progress can continue under a sustainable development regime [27].

An experiment conducted by A.A. Bayod-Rujula (2019) presented how the PV conversion is based on the PV effect which is the conversion of light energy from the sun into electrical energy, as shown in Figure 4. PV cells are sun-exposed diodes with a wide surface area. An n-type layer is connected to a p-type layer to form a diode. The junction is the area where the two layers meet. Each region contains moving particles with different charges. Meanwhile, solar cells which are made of semiconductor materials and have an artificially created constant electric field through a p-n junction are used to carry out this conversion [28].

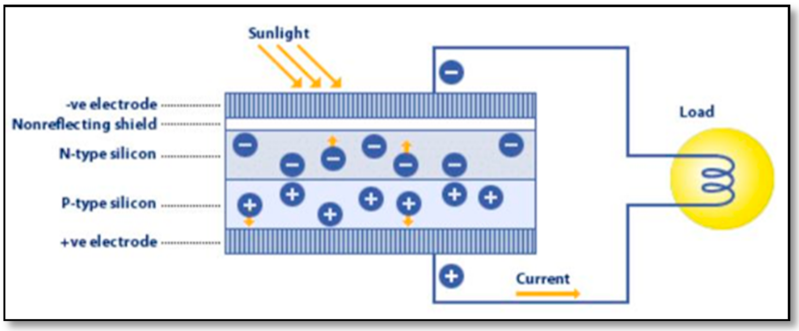

Figure 4. Conversion of sunlight into electricity [29].

According to P.J. Ribeyron (2017), PV crystalline silicon dominates the solar cell market (c-Si). Silicon has a number of significant advantages, including its widespread availability, nontoxicity, and theoretically high efficiency limit. Furthermore, electron hole pairs are formed by photon absorption within the silicon bulk, particularly in the front half of the cell, but the carriers must traverse the entire thickness of the silicon to reach the solar cell's back contacts. The majority of sophisticated processes and materials originated in the microelectronics sector, and there were only a few photovoltaic research and development laboratories. Today, as a result of ongoing research and development focused on photovoltaic (PV) technology, silicon meets these stringent standards while balancing high bulk material quality and low cost [30].

B. Sorensen discussed the differences in the substrates, glass cover materials, and films used in various types of solar panels (2020). Solar equipment decommissioning and dismantling are expected to follow recycling and reuse trends seen in the building sector more broadly, with the building industry likely serving as a forerunner. Three types of electronic circuits are relevant to photovoltaic technology: junction boxes, charge controllers, and inverters. Additionally, in some locations, dust cleaning of solar panel surfaces may be required, and electronic control equipment, such as inverters, if not adequately protected, may generate radio-frequency disturbances. Hence, cleaning methods for PV panels, such as sand, dust, and snow removal robots and techniques, are required [31].

Research reported by W.C. Sinke (2019) showed that PV conversion can be accomplished using a variety of materials, device technologies, and architectural designs that are at varying stages of technical and economic maturity. Consider the following examples: Building-Integrated Photovoltaic (BIPV), Infrastructure-Integrated Photovoltaic (I2PV), Floating Photovoltaic (PV) systems, Ground-Based Photovoltaic (PV) Power Plants, and Vehicle-Integrated Photovoltaic (VIPV). The field of photovoltaics is undergoing rapid change, and the growing interest among engineers, scientists, and business leaders has resulted in an avalanche of literature attempting to keep abreast of the latest developments. It has made significant strides in the last decade in terms of deployment scale, cost reduction, and performance enhancement [32]. Thus, solar PV energy is predicted to play a significant role in the worldwide sustainable development energy system of the future.

6.2. Comparison of the Efficiency of Solar Photovoltaics (PV) to Other Renewable Energy (RE)

The research conducted by K.H. Solangi et al. (2011) and M.D. Madvar et al. (2018) showed that solar energy sources are available that are some of the most environmentally friendly and sustainable renewable energy sources today [33,34]. Renewable Energy (RE) is the best promising alternatives to fossil fuel energy. This energy is non-polluting and has a minimal environmental impact. It is not only an RE source, but it has also emerged as a viable alternative to big transformational technology. Its development helps to reduce global warming and greenhouse gas (GHG) emissions. Solar energy also can be used to generate direct electricity by extracting its thermal content or by applying photovoltaic (PV) cells to generate direct power [34]. Thus, solar energy has become one of the most popular RE sources due to its accessibility.

K.H. Solangi et al. (2011) highlighted the different countries that have developed solar energy strategies in order to reduce their consumption of fossil fuels and increase domestic solar energy consumption. Furthermore, to overcome the harmful environmental consequences and other issues associated with fossil fuels, several countries have been pushed to investigate and switch to environmentally friendly RE sources in order to satisfy rising energy demand [33]. Solar energy, as with other renewable energy sources, is a promising and readily available source of energy for resolving the long-term energy crisis, as N. Kannan and D. Vakeesan concluded (2016). The world's energy demand is increasing rapidly as a result of population growth and technological advancements. As a result, it is critical to choose a stable, cost-effective, and eternal RE source for future energy demand. Nonetheless, it is due to the enormous demand for energy that the solar sector is steadily growing throughout the world, despite the fact that the primary energy source, fossil fuel, is finite and alternative energy sources are prohibitively expensive [35].

In the face of pressing issues, such as climate change and fossil fuel depletion, renewable energy sources are viewed as a clean and sustainable alternative. Through a large number of scientific publications and patents, photovoltaic technologies have developed into a significant field of research and development. Solar cells are the fundamental building block and primary component of photovoltaic systems. A solar cell is an electrical device that converts the energy contained in photons directly into direct current (DC) electricity via a chemical or physical process known as the photovoltaic effect. Photons with energy greater than the band gap of the cell material are absorbed, resulting in the excitation of charge carriers and thus in the generation of electric current and voltage.

The conversion efficiency of a photovoltaic cell is defined as the percentage of incident light power that is converted to electrical energy under standard conditions [9]. Besides, according to K. Sopian et al. (2017), since its inception, the solar cell of photovoltaic (c-Si) technology has been recognized as the only long-term sustainable, environmentally friendly, and economically viable renewable energy source to replace fossil fuels. The primary driver of Si photovoltaic industry development has been cost reduction in order to compete with fossil fuels. Despite its rapid maturation, the crystalline Si photovoltaic field continues to be rich in novel device concepts and optical enhancement techniques [36].

Domestic and local renewable energy sources, such as domestic and local natural resources, are critical components of government energy policies. Malaysia's energy policy which includes energy generation, supply and consumption is defined by the Malaysian government. Research conducted by M.A. Hannan et al. (2018) notes how Malaysia's government is currently attempting to increase RE production. The energy sector is regulated by the Department of Electricity and Gas Supply. Besides this, the energy suppliers, service industries, Research and Development (R&D) institutions and customers are among the other stakeholders. Petroliam Nasional Berhad (PETRONAS) and Tenaga Nasional Berhad (TNB) are government-owned companies that dominate Malaysia's energy market. In summary, regarding to Malaysian energy policies, these energy indicators are intended to encourage sustainable development [13].

G. Raina and S. Sinha (2019) informed that the high temperatures and mismatches in output from individual panels in a PV array frequently result in the formation of hotspots, which degrade the solar PV plant's efficiency. These hotspots cause severe degeneration of the PV panel over time, raising maintenance and repair costs. PV module developers must conduct quality checks to avoid the establishment of hotspots. For the producer to increase the quality and lifetime of the PV modules, standards must be established [23]. According to SEDA (2020), PV Monitoring System (PVMS) is a project that utilizes the National PV Monitoring & Performance Database to monitor the performance and reliability of selected grid-connected solar photovoltaic (PV) systems. The Akaun Amanah Industri Bekalan Elektrik (AAIBE) and the Malaysian Electricity Supply Industries Trust Account are funding this program (MESITA). To begin, 148 grid-connected solar photovoltaic (PV) installations in Malaysia with a capacity of up to 1MW are being monitored in real time. Hence, subscriptions are required to access data and system performance analyses. In the future, the database will serve as a guide for developing national energy policies and for this programmed [15].

Lastly, M. Vaka et al. (2020) argued that the government launched a number of new initiatives and plans in response to the solar energy potential and, more broadly, renewable energy. Net Energy Metering (NEM), Feed-In Tariffs (FIT), Large-Scale Solar (LSS), Consumption (SELCO), and Renewable Energy (RE) incentives are just a few examples of programs aimed at reducing bills and fiscal burdens in the pursuit of a carbon-free environment. Malaysia's government is concentrating its efforts on renewable energy and energy efficiency in order to reduce electricity bills and carbon dioxide (CO_2) emissions. Indeed, Malaysian RE is a supporter of the ministry's solar photovoltaic (PV) initiative to capture excess energy via the Net Energy Metering (NEM) program [37]. The Malaysian government has taken these initiatives and implemented numerous different programs to promote renewable and clean energy using the different technologies indicated in Figure 5.

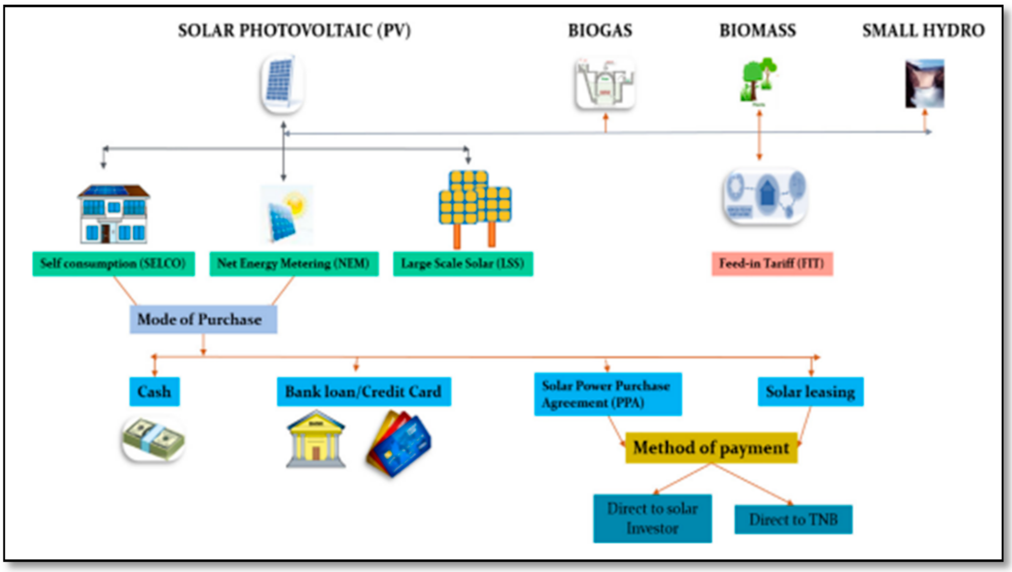

Figure 5. Implementation of program using different technologies to improve Renewable Energy [37].

7. Framework and Advancement of Renewable Energy Sources

On a geographical level, several European Union member states, including Switzerland, Germany, Austria, Sweden, and Denmark, have pioneered a new approach to solar planning, demonstrating that it is possible to maximize solar energy utilization while maintaining a site's heritage and architectural integrity. In Italy, on the other hand, a big debate erupted following the implementation of several medium-sized installations in famous locations with the assistance of state economic incentives. According to E. Lucchi, C. S. Polo Lopez, and G. Franco (2020), on 30 May 2018, the European Parliament adopted Directive (EU) 2018/844 on the energy performance of buildings, establishing a specific legislative framework for reducing CO_2 emissions by 2020, increasing the share of renewable energy sources (RES), and improving the energy performance of existing buildings. The study examines the most major research programs, grants, and awards honoring historical RES.

Furthermore, the research provides a high-level overview of the fundamental recommendations for heritage rehabilitation, preservation, and sustainability. The fundamental contribution is a conceptual framework that provides a holistic view on the evolution of solar energy system integration in historic structures and places. Despite the physical limitations outlined above, the most preferred strategy in cultural heritage is the incorporation of BIPV systems into building components. Initially, studies concentrated on the acceptability of PV and BIPV technologies in heritage contexts. A comprehensive knowledge base on BIPV and BIST solutions in building renovation was built a few years later, particularly to demonstrate their advantages, such as technical competitiveness, economic savings, and building protection, or to reach high-quality standards of solar architecture. It was advocated in various examples of BIPV and BIST systems to preserve original shapes, characteristics, and values. The establishment of active collaboration with local and heritage agencies was a critical step for academics seeking unknown solutions based on local laws and policies [38]. As an example, consider the localization of alternative structures near heritage sites. Hence, RES integration in heritage environments is being thoroughly investigated in international, EU and local research programs.

The digitalization of industry, often known as Industry 4.0, is driving the advancement of renewable energies. It is known as the fourth industrial revolution and it comprises of the use of advanced digital technologies, such as Internet of Things (IoT), Big Data analytics and cyber-physical systems, to improve the industry's production and performance. According to these authors, I. Arcelay et al. (2021), achieving sustainability is also a crucial goal of Industry 4.0, which enables the efficient consumption of material and energy resources. As a result, the renewable energy sector benefits from industry-wide digital transformation, as developments driven by Industry 4.0 in most sectors will probably encourage the use of renewable energy resources, boosting their presence and participation in the energy system. Renewable energy technologies can boost efficiency while also allowing for improved equipment maintenance over time. Predictive maintenance is a rising method in the renewable energy market for reducing operations and maintenance costs for this reason [39].

Another study, by J. Liu (2019), also highlighted that China has produced a succession of five-year, medium-term, and long-term plans outlining guidelines and targets for the promotion of renewable energy. These national plans hold unique positions in the system of renewable energy law and policy and can sometimes provide more efficient implementation effects than laws. To date, China has established a comprehensive renewable energy legal system that is mostly based on the Renewable Energy Law (REL) and complemented by other related laws and regulations. To put the REL into effect, the central ministries and local governments have developed a set of department regulations, local government rules, and other regulatory instruments [40]. Thus, the REL is China's fundamental law governing the exploration and utilization of renewable energy.

8. Conclusions

This article provided a thorough evaluation of several viewpoint possibilities, examining the barriers, challenges, and comparisons of each flexibility option in detail. The article also examined background information on the Sustainable Development Goals (SDGs), green building, BREEM, LEED and energy efficiency. The critical literature review finally showed Renewable Energy (RE) as the best promising alternative to fossil fuel energy. This energy is non-polluting and has a minimal environmental impact. The use of solar energy technologies called solar energy systems, in buildings such as solar thermal and photovoltaic (PV), provide significant environmental benefits, contributing to the long-term development of human activities. In order to meet rising energy demand while mitigating the negative environmental impacts and other issues associated with fossil fuels, many countries have investigated and switched to environmentally friendly renewable alternatives. The most significant benefit of using renewable energy sources is that it reduces pollution, particularly greenhouse gas emissions. This is accomplished by reducing atmospheric emissions by substituting fossil-based power and conventional fuels. Renewable energy could become one of the alternative sources of environmental, health, political, economic, and social well-being for people living in cities. Solar PV holds enormous promise for reducing energy-related emissions and contributing to climate change mitigation. As photovoltaic generating systems improve their efficiency and continue to decrease in cost, they are expected to play a significant role in the coming years. For proper application of solar energy resource prospects, participation, collaboration, and integration from the government, private sector, non-governmental organizations, and local community are required. Furthermore, the application of the STEEP model can be implemented and considered in a future study of solar PV in any country. Thus, solar PV energy is predicted to play a significant role in the worldwide sustainable development energy systems of the future.

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