sustainability

MDPI

Review

Opportunities, Challenges, and Future Prospects of the Solar Cell Market

Amal Bouich [1,2,*], Inmaculada Guaita Pradas [2], Mehwish Aziz Khan [3] and Yousaf Hameed Khattak [3]

1 Department of Applied Physics, Institute of Design and Manufacturing (IDF), Polytechnic University of Valencia, 46022 Valencia, Spain
2 Economics and Social Science Department, Faculty of Business Administration and Management, Polytechnic University of Valencia, 46022 Valencia, Spain; iguaita@upv.es
3 Federal Urdu University of Arts, Sciences and Technology, Islamabad 75300, Pakistan; khanmehwish1986@gmail.com (M.A.K.); yousaf.hameedk@gmail.com (Y.H.K.)
* Correspondence: ambo1@doctor.upv.es

Abstract: The production and consumption of energy must be converted to renewable alternatives in order to meet climate targets. During the past few decades, solar photovoltaic systems (PVs) have become increasingly popular as an alternative energy source. PVs generate electricity from sunlight, but their production has required governmental support through market interventions due to their lack of competitiveness on the energy market. Despite 40 years of attempts to establish PV technology through such interventions, the aim of this paper is to find out what general conclusions can be drawn regarding different technologies. Our study examines peer-reviewed studies from the start of PV technology up to 2023 to answer these questions. The literature indicates that not only developed countries but also developing and emerging nations possess significant potential to mitigate the adverse effects of climate change by adopting renewable energy sources. Leading market players can offer support to these less developed countries by subsidizing both equipment and installation processes. As a result, this initiative can contribute to sustainable development on our planet.

Keywords: market barrier; solar energy (PV) market; institution; intervention

check for updates

Citation: Bouich, A.; Pradas, I.G.; Khan, M.A.; Khattak, Y.H. Opportunities, Challenges, and Future Prospects of the Solar Cell Market. *Sustainability* **2023**, *15*, 15445. https://doi.org/10.3390/su152115445

Academic Editor: Francesco Riganti Fulginei

Received: 20 September 2023
Revised: 12 October 2023
Accepted: 17 October 2023
Published: 30 October 2023

1. Introduction

In order to effectively combat the leading cause of climate change—energy production and consumption, responsible for approximately 60% of greenhouse gas emissions—a rapid and efficient transition to renewable energy sources is imperative [1]. The escalation of global energy demands, driven by economic growth and rising incomes, underscores the pressing need for the swift expansion of renewable energy production [2]. Geothermal, hydro, wind, and solar energy emerge as pivotal players in this transition, offering clean, sustainable, and abundant alternatives devoid of harmful emissions [3].

Nevertheless, navigating this intricate transition requires substantial investments in technology, infrastructure, and workforce development [4]. The substantial benefits of this shift include not only improved public health and heightened energy security but also a substantial reduction in greenhouse gas emissions [1]. It is crucial for governments, businesses, and individuals to collaborate in creating an enabling environment that fosters the flourishing of renewable energy technologies [4]. Furthermore, the sustained emphasis on developing markets for renewable energy sources is vital for nurturing innovation and competencies in the sustainable energy sector [2].

According to the International Energy Agency (IEA) report, the global electricity market comprised approximately 26 percent renewable energy by the end of 2018 [5]. The share of renewable energy production in total production needs to increase to meet climate goals based on present consumption levels. In order to foster the rapid growth of renewable energy production and meet the rising demand, governments play a vital role in creating market conditions that incentivize both new and existing firms to invest in innovative technologies. Solar energy and photovoltaic systems (PVs) are becoming more popular as renewable energy options. Solar panels can convert solar energy into electricity and are a cleaner, quieter alternative to fossil fuels. In recent years, numerous forms of renewable technology have undergone remarkable growth, and this particular technology stands out among them. While its contribution to overall energy production was around 2.4 percent in 2018 [6], it accounted for an impressive 55 percent of the additional capacity added to the renewable energy sector.

The share of renewables in the global power generation mix is forecast to rise from 29% in 2022 to 35% in 2025. Renewables saw a year-on-year rise of 5.7%, making up almost 30% of the generation mix in 2023 [7].

The global installed capacity of renewables is estimated to have increased at a faster year-on-year rate of almost 11% in 2022 compared to the average 9% growth seen in the 2017–2021 period. Variable renewables—wind and solar PVs—continued to see strong growth in combined capacity, up nearly 18%. This corresponds to about 300 GW in the additional installed capacity of variable renewables, which is greater than the current combined wind and solar PV cumulative capacity in the United States (approximately 280 GW) [7].

2. Solar Cell Markets, Opportunities, and Challenges

Market theory defines an ideal market as having many market actors that facilitate the entry and exit of buyers and sellers. Supply and demand play an important role in determining the price in this kind of market. It is therefore important that the government does not interfere with the equilibrium of the market. Such markets can be referred to as natural markets. Although this is true, markets are rarely or never completely efficient in reality. Businesses often face numerous challenges when entering or operating in a particular market. Several factors must be considered and invested in before a company enters or competes in a market, according to the literature on market structure and strategy. A number of barriers must be overcome in order for them to survive a market [8].

It is possible for established companies to gain technological and cost advantages as well as important business relationships that will create barriers for newcomers. PV-based firms may therefore face different barriers to entering the energy market if they wish to enter. The barriers may be financial limitations, such as high initial or production costs; market barriers, such as unadopted markets; unclear or unsuitable regulations; or firm-level barriers, such as an inability to develop business models, competence, or reliability. It is possible to have oligopolies or monopolies that restrict future entry into a market with high entry barriers [9,10].

Economic sociology has pointed out that the traditional view of market structure and strategy, as presented above, often overlooks the role institutions play in determining how markets develop because markets are not always efficient, as shown above. A term such as institutions can be used here to describe human-made constraints that govern political, economic, and social interactions. In addition to codified laws and regulations, informal norms influence the market's structure and behavior [11,12]. Companies that have already established themselves in a market often enjoy financial and technological advantages, as well as valuable business relationships, which can create obstacles for newcomers. As a result, firms relying on PV-based technologies may face different types of barriers when seeking entry into the energy market. These barriers could include financial hurdles such as high initial or production costs, structural barriers like underdeveloped markets or unclear and unsuitable regulations, and firm-level challenges such as a lack of expertise or suitable business models, or unreliable value chains. The presence of high entry barriers may contribute to a market structure characterized by oligopolies or monopolies, limiting future entry and competition [9].

Economic sociology highlights the significance of institutions in shaping market development, a perspective often overlooked by the traditional view of market structure and strategy described earlier [13,14]. Institutions encompass human-made constraints that govern political, economic, and social interactions. In addition to codified laws and regulations, informal norms also influence market behavior and structure, challenging the notion of market efficiency highlighted earlier [15,16]. Due to the fact that governments can design formal institutions to regulate and shape market structures, they play an important role in market construction, which includes regulating and shaping market structures [17].

When institutions are efficient, they create stable, favorable conditions for market actors to exchange ideas. Inefficient institutions are those whose regulations are perceived as unstable or unfavorable, creating uncertainty and leading to market participants hesitating before doing business. An efficient market mechanism maintains a well-functioning market, whereas an ineffective one counteracts it. State-building activities strive to establish stable, long-term, and efficient markets that closely resemble the theoretical model of a perfect natural market [18]. However, it is important to acknowledge that governments may sometimes seek to steer or influence the market for political purposes. Politicians and society may intervene when markets produce undesirable outcomes, regardless of how efficient they are. When renewable energy alternatives are constrained, governments may need to intervene in energy markets in order to convert them from traditional to renewable sources [19]. To put it another way, governments have the ability to employ political market regulation as a tool to encourage the adoption of preferred behaviors, such as the use of renewable energy. They can achieve this through various means, including implementing taxes, enacting legislation, providing financial support, offering assistance programs, and granting subsidies. Specific to PV technology, common measures include feed-in tariffs (FIT) and net metering. By intervening in the market, government actions can either stimulate or hinder its growth, impacting both existing market players and new entrants, as they may contradict fundamental market principles. In cases where the government is dissatisfied with market outcomes, it may consider reshaping the market structure.

Government interventions in the market can introduce instability and uncertainty, leading to inefficient market functioning. As a result, it is commonly advised to gradually reduce these interventions once the political objectives behind them have been successfully attained [20,21].

It is crucial to differentiate between two distinct forms of market interventions: those guided by economic considerations and those driven by political motives. Economic interventions are employed when a market fails to function efficiently from an economic standpoint. On the other hand, politically motivated interventions involve reconstructing or even dismantling the market to align its functioning with that of a natural market. It is important to recognize that any intervention, regardless of its nature, will impact the market and its participants [22].

The extent of change in market structure and the manner in which business is conducted are intricately tied to innovation. PV systems, as a technological innovation, hold great potential in driving the transition towards renewable energy production and consumption [23]. Consequently, they should be embraced as an alternative to traditional energy sources. However, integrating these innovations into existing energy market structures is not without challenges. The replacement of established technologies with new ones presents difficulties. Research, production, marketing, and installation are complex, multifaceted activities that require collaboration among various stakeholders to successfully bring technological innovation from the laboratory to the end customer [24]. In this regard, governments may employ politically motivated interventions to support the adoption of PV systems and foster markets that favor this technology. Nonetheless, it is important to note that such initiatives may temporarily disrupt the functioning of a natural market.

3. Solar Photovoltaic (PV)

Sunlight is converted to electricity using solar photovoltaic (PV) systems. Before 2000, most solar PV markets consisted of off-grid PV systems (no electricity grid connection). Recent increases in installation rates are largely due to grid-connected systems. Depending on the size of the system, companies or private households can either distribute the energy produced or sell overcapacity back to the grid. Solar PV technology expansion has been driven largely by financial incentives for self-consumption [5,19], such that the consumer has expanded into a producer or a "prosumer". PV technology has grown from being developed for specific markets [25] to a stage where increased efficiency has led to reduced production costs, more interest from traditional firms, and, therefore, more demand [26,27]. Because of that, technology has entered previously centralized markets dominated by a few powerful and large players. Mass production and mass markets have replaced small niche markets. Competitive players have emerged as a result of standardized PV technology, homogeneous products, and policy reforms [7]. China, the United States, Japan, Germany, India, and Brazil were the largest solar PV markets in 2021. These countries account for 69% of total solar PV capacity worldwide, a highly concentrated market comprising both single households and large companies [28,29].

4. The Uses of Solar PV Energies: State of the Art

4.1. Solar PV Energy

Photovoltaic energy is derived from the conversion of solar radiation into electrical energy with a suitable efficiency. When sunlight reaches the Earth's surface, it consists of photons that can either be absorbed or reflected. In the field of solar cell technology, various technologies are employed, but the most commonly used one is the solid-state semiconductor solar cell. These cells utilize semiconducting materials to convert sunlight into electricity. The absorber film in such cells can be made of amorphous, crystalline, or polycrystalline semiconductor materials. Silicon and GaAs solar cells are considered the most efficient among them.

In recent years, researchers have shown great interest in perovskite AXB3 and Cu(In, Ga)Se2 (CIGS) materials due to their excellent light absorption properties [30] and ability to reduce the thickness of the cell layers from 100 μm to just a few μm. This characteristic allows for the fabrication of low-cost solar panels using simple techniques. Semiconductor materials used in these cells have a valence band (VB) and a conduction band (CB), which are separated by a forbidden energy gap known as the band gap (Eg). At a temperature of 0 K, the valence band is completely filled with electrons, while the conduction band is unfilled [7].

4.2. Solar Cell Technology

The study of photovoltaic solar cells has been primarily focused on enhancing their efficiency for autonomous applications. These solar cells are classified into three generations, and researchers are diligently working on all three levels: improving overall performance, developing cost-effective fabrication techniques, and reducing the reliance on toxic materials to ensure environmental sustainability [31,32].

4.2.1. First Generation: Crystalline Si Solar Cells

Solar cells that utilize amorphous silicon, in contrast to crystalline silicon (c-Si), have shown efficiency levels ranging from 6% to 44.0%. However, the production of pure silicon crystals is expensive, making mass production impractical. Additionally, monocrystalline silicon solar cells demonstrate higher efficiency at elevated temperatures. Although monocrystalline silicon cells are more efficient, they are less expensive because they are composed of multiple silicon crystals molded together. Despite the first-generation technology being up to 44% more efficient than crystalline silicon (c-Si) solar cells, its cost remains higher [33,34].

4.2.2. Second PV Generation: Thin-Film Solar Cells

Thin-film solar cells based on amorphous silicon, polycrystalline CdTe, and polycrystalline Cu(In, Ga)Se2 (CIGS) are prominent technologies in the second generation of solar cells. These technologies have gained popularity due to their low-cost manufacturing requirements. Various methods, such as electrochemical deposition, chemical bath deposition, spray pyrolysis, and spin coating, are employed to fabricate thin-film solar cells, offering versatility in their production. The cost-effectiveness and large-scale production capabilities of second-generation solar cells make them particularly attractive for integration into the industrial sector [12]. Notably, thin-film solar cells are available in three main types: amorphous silicon (a-Si), cadmium telluride (CdTe), and chalcopyrite compounds like copper indium gallium selenide (CIGS) [33,35].

4.2.3. Third-Generation Solar Cells

Third-generation solar cell technology commonly employs multi-layer (tandem) cells, which are composed of a hierarchical structure combining silicon and thin film materials. Among these thin film materials, copper zinc tin sulfide (CZTS) and perovskite solar cells have garnered significant attention [36,37]. In particular, perovskite solar cells have recently achieved research efficiencies exceeding 20 percent, making them a highly promising technology [34,38]. Dye-sensitized solar cells (DSSCs) also represent a third-generation photovoltaic technology. These cells use a semiconductor coated with a photosensitive dye to generate an electric current. DSSCs offer cost-effectiveness in production and flexibility in design, allowing integration into various surfaces. However, challenges persist in terms of stability under harsh conditions and achieving higher efficiency. Organic solar cells (OSCs) utilize carbon-based materials in the active layer, providing flexibility and potential cost savings in manufacturing [39,40]. They are lightweight, adaptable, and suitable for unconventional form factors. Despite advantages, organic solar cells face challenges such as lower efficiency than traditional silicon cells and concerns about long-term stability. Both DSSCs and OSCs share common challenges related to stability and efficiency. Researchers are actively addressing these issues to enhance overall performance. These third-generation technologies show promise in specific applications like building-integrated photovoltaics and portable electronics, but wider adoption depends on overcoming efficiency and stability constraints through ongoing research and development efforts [41–43].

5. Production of Electricity from Photovoltaic Sources: State of the Art

The landscape of solar cells is marked by both opportunities and challenges, with promising future prospects. The cost of electricity generation from solar photovoltaic (PV) technologies has notably decreased, rendering them competitive with fossil-fuel-based technologies and onshore wind power [44]. This cost reduction is crucial for addressing global climate change, positioning solar PVs as a cost-effective solution [45]. To harness these opportunities, the ongoing trend of cost reductions must persist, especially considering that a substantial portion of the costs associated with solar PV systems scales with the size of PV modules.

Increasing the efficiency of solar PV systems stands out as a viable strategy for reducing the levelized cost of electricity (LCOE). While silicon-based PV technology presently dominates the market, its efficiency is fundamentally limited to 29.4% [46,47]. Silicon-based tandem solar cells, however, offer practical efficiency beyond 33% [48–50], representing an evolutionary advancement from traditional silicon technology.

Despite the advancements, there are concerns about whether tandem devices can offset the additional cost of the top cell in terms of LCOE. Moreover, perovskite-based single-junction solar cells may hold potential in achieving a low LCOE. To comprehensively assess the most cost-effective solution, a comparison between tandem technologies and individual cell technologies for both bottom and top solar cells is necessary.

This article aims to explore the opportunities, challenges, and future prospects of the solar cells market, focusing on the LCOE of silicon and perovskite technologies in single-junction and tandem configurations. Additionally, the analysis will extend to estimating the manufacturing cost of a perovskite-based solar cell module [51]. It is imperative to consider the ongoing cost reductions in silicon technology and the development of balance-of-system (BoS) technologies, given that perovskite-based production methods are not yet widely available. The key parameters in the cost analysis include the potential efficiency increase achievable with tandem devices and the equivalent efficiency that a single-junction perovskite device could attain. This comprehensive examination, drawing from existing literature, will facilitate direct comparisons between perovskite/silicon tandem cells and perovskite/silicon cells alone [52].

6. Solar Energy Development in World Markets: An Economic Perspective

Solar energy has become a prominent contributor in the worldwide shift towards eco-friendly and renewable energy sources. As the world faces pressing environmental challenges and seeks to reduce greenhouse gas emissions, solar power has gained significant momentum [53–55]. The future of the solar energy market in both developed and developing nations holds tremendous potential. Market research and numerous reports have shown that the value of the global solar cell market was approaching $40 billion in 2020, and between 2021 and 2028, this value is expected to upsurge at a compound annual growth rate (CAGR) of more than 15% [56].

Developed economies continue to focus on technological advancements, grid integration, and supportive policies to further solidify their position as leaders in solar energy adoption. On the other hand, developing economies have a unique opportunity to leverage solar energy to meet their growing energy demands sustainably. With increasing affordability, supportive policies, and a commitment to sustainable development, these countries can rapidly expand their solar energy capacity [54]. Ultimately, the global transition to solar energy requires collaboration between developed and developing nations, as well as the sharing of knowledge and resources. By embracing solar power, both types of economies can contribute to a greener, more sustainable future for generations to come.

According to Renewables 2022 Global Status Report, China achieved a significant milestone in 2021 by becoming the first nation to exceed an installed capacity of 1 terawatt (TW) in renewable energy [57]. Throughout the year, China witnessed an impressive increase of 136 GW in total installed capacity, accounting for approximately 43% of global additions. Notably, China experienced substantial growth in solar power, accounting for approximately 31% of worldwide additions in solar photovoltaic (PV) capacity [58,59]. Moreover, China dominated capacity additions across various other renewable energy technologies. For instance, the country marked additions of 14.5 GW in offshore wind power and almost 80% in global hydropower. China is considered a leading player in the world markets of hydropower, solar PVs, bio-power, and wind power, as shown in Table 1. Between 2020 and 2021, certain countries experienced significant changes in total power capacity and demand, as indicated in Table 2.

Table 1. Net capacity additions/sales/production (top five countries in 2021).

Net Capacity Additions/Sales/Production in 2021 *Technologies Ordered Based on Total Capacity Addition during 2021*					
	5	**4**	**3**	**2**	**1**
Hydropower capacity	Lao PDR	Nepal	India	Canada	China
Wind power capacity	United Kingdom	Vietnam	Brazil	United States	China
Solar PV capacity	Brazil	Japan	India	United States	China
Solar water heating capacity	United States	Brazil	Turkey	India	China

Table 1. *Cont.*

Net Capacity Additions/Sales/Production in 2021 *Technologies Ordered Based on Total Capacity Addition during 2021*					
	5	**4**	**3**	**2**	**1**
Biodiesel production	France	Germany	United States	Brazil	Indonesia
Ethanol production	India	Canada	China	Brazil	United States
Air-source heat pump sales	Italy	France	United States	Japan	China
Concentrating solar thermal power (CSP) capacity	-	-	-	-	Chile
Geothermal power capacity	New Zealand	Japan	Iceland	Turkey	China

Table 2. Total power capacity or demand/output as of year's end, 2021.

Total Power Capacity or Demand/Output as of End 2021 *Countries in Bold Indicate Change from 2020*					
	5	**4**	**3**	**2**	**1**
Power					
Renewable power capacity per capita (Not including hydropower)	Australia	Sweden	Germany	Denmark	Iceland
Renewable power capacity (Not including hydropower)	Japan	India	Germany	United States	China
Renewable power capacity (Including hydropower)	Germany	India	Brazil	United States	China
Solar PV capacity	Germany	India	Japan	United States	China
Geothermal power capacity	New Zealand	Turkey	Philippines	Indonesia	United States
Wind power capacity	Spain	India	Germany	United States	China
Hydropower capacity	Russian Federation	United States	Canada	Brazil	China
Concentrating solar thermal power (CSP) capacity	South Africa	Morocco	China	United States	Spain
Bio-power capacity	Germany	India	United States	Brazil	China
Heat					
Geothermal heat output	New Zealand	Japan	Iceland	Turkey	China
Solar water heating collector capacity	Brazil	Germany	Turkey	United States	China

In addition to China's achievements, countries outside of China witnessed significant growth in renewable energy capacity during 2021. These countries collectively added approximately 179 GW of new capacity, representing a 29% increase from the previous year. The leading contributors to this growth were the United States with 42.9 GW, India with 15.4 GW, Brazil with 10.2 GW, Germany with 7.3 GW, and Japan with 7.2 GW. However, it is important to note that China maintained its leading position in cumulative renewable energy capacity by the year's end. The United States followed with 398 GW, while Brazil, India, and Germany reached capacities of 160 GW, 158 GW, and 139 GW, respectively [60,61].

Developed economies have been at the forefront of solar energy adoption, driven by technological advancements, supportive policies, and increasing environmental awareness. These countries have made substantial investments in solar infrastructure, resulting in widespread installations and well-established markets. The future of solar energy in developed nations is promising, with a focus on further enhancing efficiency, storage capabilities, and grid integration [62,63].

Developing economies frequently encounter substantial energy requirements resulting from population expansion and the process of industrialization. A significant role can be played by solar energy in meeting this demand, especially in regions with abundant sunlight. Solar installations can be rapidly deployed, even in remote areas, bypassing the need for extensive grid infrastructure. The Nigerian government has recognized the compelling advantages of solar energy as a smart approach to meet the power needs of households in the country. Geographically, Nigeria has great potential for solar energy deployment. Analysts have estimated that even by utilizing a mere 1% of Nigeria's landmass for solar PV panels, the country could generate an impressive 600,000 MW, as reported by Financial Nigeria International. This demonstrates the immense feasibility and potential of solar energy in Nigeria. India has established a formidable target of achieving a solar capacity of 100 GW by the year 2030 [64,65]. To support this objective, the Indian Ministry of New and Renewable Energy has implemented various programs aimed at assisting private solar power enterprises through the provision of subsidies. Additionally, India plans to explore innovative approaches, such as installing photovoltaic (PV) panels on canal tops and integrating them with the grid. This unique concept of integrated solar power generation has the potential to revolutionize the industry. Furthermore, India benefits from its favorable geography, characterized by clear skies for approximately 300 days a year and abundant solar radiation, making it an ideal location for solar energy deployment. Pakistan possesses abundant solar irradiance, allowing for the harnessing of solar energy throughout the majority of the year. This presents a remarkable opportunity to leverage solar power from highly irradiated locations within the country, supplemented by foreign investments [66,67].

Solar energy has become increasingly cost-effective, and developing economies can benefit from this trend. With decreasing solar panel costs and access to financing mechanisms, such as international loans and partnerships, these countries can embrace solar power as a reliable and affordable energy source. In Kenya, the cost of a 195 W solar panel has decreased from $1000 in 2007 to $150 today. This decline in prices can be attributed to the removal of value-added taxes and import duties on renewable energy equipment. According to an analysis conducted by IRENA (International Renewable Energy Agency), the costs associated with establishing solar PV projects in India have significantly decreased by approximately 80% between 2010 and 2018. As a result, solar energy in India is now available at a lower cost compared to traditional fossil fuel energy sources. The government under Prime Minister Modi highlights that although solar energy systems include the added expense of batteries, they anticipate that solar energy will soon become more cost-effective than relying solely on the grid. KPMG, a reputable consulting firm, predicts that by 2024, around 20% of households in India will have adopted photovoltaic (PV) systems [54].

A report by Mordor Intelligence emphasized that supportive government policies and programs are expected to increase the development of the solar energy market in Pakistan during the projected period (2023–2028). In pursuit of renewable energy alternatives, the Pakistani government has established ambitious targets, aiming to attain a minimum of

20% of electricity generation from renewable sources by 2025 and 30% by 2030, as explained in the Alternative and Renewable Energy (ARE) Policy of 2019 [68].

According to the policy, machinery and imported plant equipment used in the production of alternative renewable energy technology end-consumer items including solar panels are exempted from tax to encourage the adoption of solar energy. Under this policy framework, the Alternative Energy Development Board plans to establish an Institute of Renewable Energy Technologies. This institute will focus on providing academic qualifications and conducting research in the domain of renewable energy, including solar energy. Additionally, the Pakistani government has implemented a net metering scheme that enables residential solar system owners to contribute excess electricity to the grid, earning credits and making residential solar energy systems financially attractive. This incentivizes the adoption of solar energy at the residential level. Overall, Pakistan's favorable solar irradiance, coupled with supportive government policies and programs, demonstrates the country's commitment to expanding its solar energy sector and embracing renewable energy as a key component of its energy mix [69].

Despite the numerous opportunities and concerted efforts directed towards the adoption of solar energy to meet market needs, certain challenges and barriers still persist. As of mid-2022, the global energy landscape faced an unprecedented energy crisis. The situation was further compounded by the upsurge in prices of fossil fuels, including coal, oil, and natural gas, since the end of 2021 and the Russian Federation's invasion of Ukraine in February 2022. This surge in prices posed a significant threat of energy poverty for billions of individuals worldwide. Despite compelling evidence showcasing the affordability of renewable energy as a means to enhance resilience and facilitate decarbonization, governments worldwide persist in relying on fossil fuel subsidies to maintain control over energy costs. This disparity between countries' aspirations and actual implementation is concerning and represents a cautionary signal indicating that the global energy transition is not advancing as anticipated [70–72].

In light of apprehensions regarding energy security, various regions have undertaken assessments of their energy policies. For instance, the European Union (EU) set a goal to minimize its dependence on Russian gas by 60% by the end of 2022 and completely eliminate it by 2030. This objective involves implementing measures such as doubling renewable hydrogen production and scaling up its utilization. Additionally, the recently unveiled REPowerEU plan seeks to double the EU's capacities for solar photovoltaic (PV) and wind energy by 2025, with a further aim to triple them by 2030. These initiatives demonstrate a commitment to diversify energy sources and enhance sustainability in the pursuit of greater energy security [73,74].

Germany is actively pursuing an accelerated transition to renewable energy, which is now referred to as "freedom energy." The country has established a goal of achieving a 100% renewable electricity supply by 2035. By 2030, Germany aims to have 80% of its electricity generated from wind and solar power, including significant expansions in capacity. These expansions include a three-fold increase in solar energy capacity to reach 200 GW, a doubling of onshore wind energy capacity to 110 GW, and the establishment of offshore wind energy capacity of 30 GW. Similarly, the United Kingdom has contemplated easing planning restrictions on onshore wind farms as a means to facilitate the rapid growth of renewable power and reduce reliance on gas imports [75].

Meanwhile, Spain is expediting the approval process for wind power projects of up to 7 megawatts (MW) and solar PV projects of up to 150 MW. Additionally, Spain is embracing floating solar PV systems and implementing measures to facilitate the self-consumption of solar energy. These countries' initiatives highlight their commitment to advancing renewable energy deployment and transitioning away from traditional fossil fuel sources, showcasing their determination to achieve greater sustainability and energy independence [76,77].

Japan is intensifying its initiatives to advance offshore wind power projects, primarily driven by the anticipated long-term rise in oil prices following the Russian invasion of

Ukraine. In response, Japan is revising its tender process for wind farms, considering not only the price but also the speed of project development. This adjustment emphasizes the urgency of transitioning to an efficient and renewable-based energy system globally, particularly in light of the increased focus on energy security. By adopting such a system, countries can align with ambitious climate goals while mitigating the risks associated with fossil fuel dependency, including price volatility and political pressures that affect both consumers and industries [78].

As the global focus on combating climate change intensifies, renewable energy sources are gaining significant prominence, with solar power expected to play a pivotal role. The International Energy Agency (IEA) anticipates that solar energy will emerge as the largest source of electricity worldwide by the year 2050. This projection underscores the growing recognition of solar power's potential in meeting our energy needs while reducing carbon emissions and advancing sustainability [79].

Socio-Economic Benefits of Solar Energy

One of the critical factors in economic growth and development is energy. To meet the upsurge in energy demand caused by increasing populations and growing economies, solar energy offers an ideal solution since the counterparts of renewable energy can be damaging to the environment. The prime advantage of solar PV systems is their free source due to the abundance of sunlight in nature. Moreover, these systems avoid carbon emissions and are basically nature-friendly. Currently, research is focused on technologies that improve the efficiency of energy conversion and reduce its cost [80]. Ref. [81] graphically presents the increase in the installation capacity of solar energy worldwide, as shown in Figure 1.

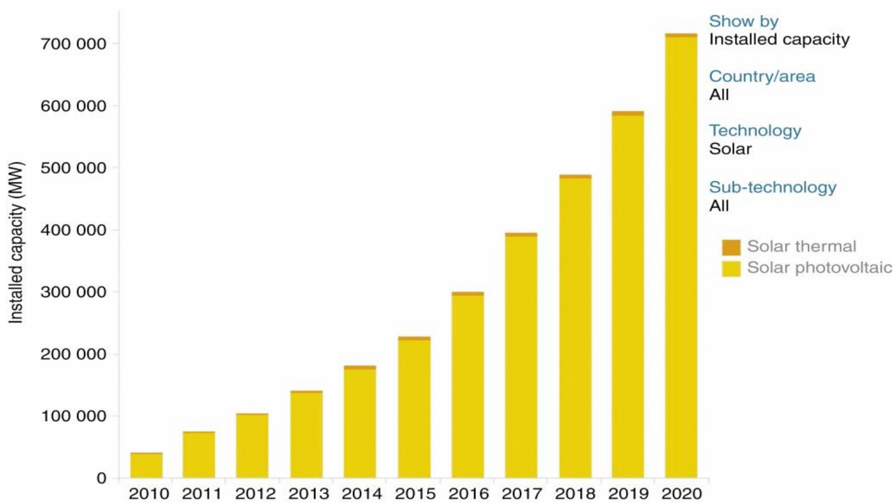

Figure 1. Worldwide increase in the installation capacity of solar energy [81].

The literature usually does not discuss emergent solar technology's social and economic impacts. There are certain limits to the quality of life for people due to the lack of access to electricity, especially in rural areas. Solar energy can overcome this problem at a very low cost without harming the environment [82]. People may have a positive impact socially; for instance, they can access more information through electric devices like TV, etc., improving the ease of mobility, and promoting security, especially during the nighttime [83]. Moreover, one of the major economic activities, the creation of employment opportunities, can be fostered through the availability of energy, leading to sustainable development and improvement [84].

To reduce the impacts of changing climate, the usage of renewable technologies would have to increase since climate action is one of the significant sustainable development goals (SDGs) developed by the United Nations General Assembly. In the past, the fossil fuel and gas sectors were the two energy generation sources. However, their intensive use significantly affects the environment in the form of the emission of hazardous gases, resulting in global warming [85]. This environmental damage leads to low quality of life, as the fuel produced is relatively costly. Comparatively, sustainable economic growth can be achieved through affordable and clean energy produced by solar energy [81,86]. The first goal of reducing poverty in the path of sustainable development can also be achieved through the rise of job opportunities in the solar sector. The International Renewable Energy Agency (IRENA) has reported that approximately 3.8 million people were employed in the global solar industry in 2019 and expecting the same pace of growth in the future.

Due to the benefit of low costs, many developing nations are more interested in investing in solar energy to meet energy demands; consequently, the adoption of solar technologies fulfills the basic needs of food and shelter, health, and education and uplifts society [87]. Solar power becomes increasingly competitive with traditional energy sources due to the decline in the cost of solar panels. In the long run, with the installation of solar panels, individuals and organizations can generate their own electricity, which will eventually save money and reduce their reliance on grid power. Through this cost reduction, consumers and businesses receive low electricity bills, and more resources are available for future investments [88].

Another interesting reason behind developing countries' significant energy production potential is the sunny nature of these localities. Their geographical locations along the equator or near deserts allows them to absorb optimal sun rays, since PV systems work perfectly in these settings. According to [89], India has the highest score in solar PV technology among the top ten countries that invest in renewable energy sources, as shown in Figure 2.

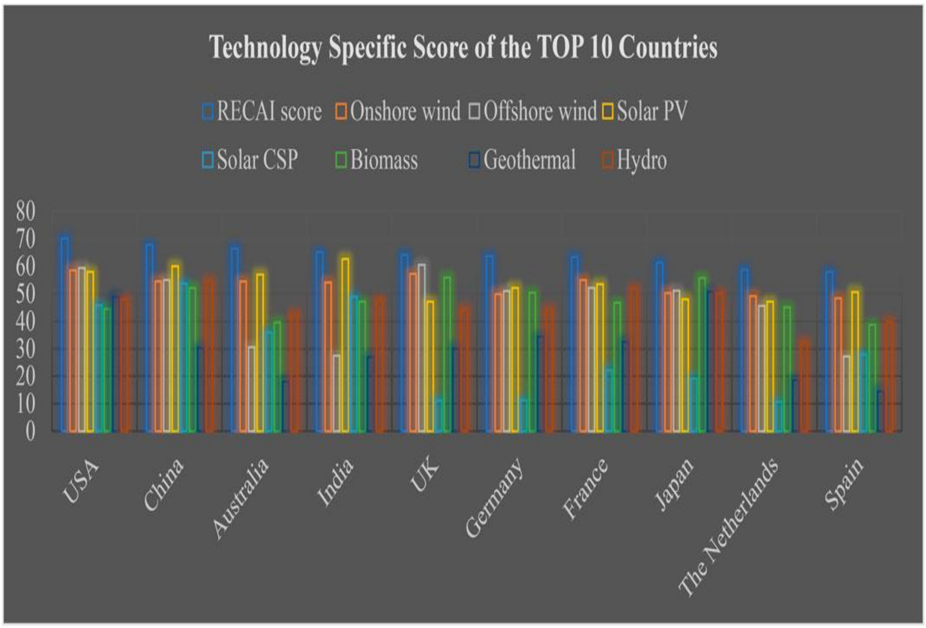

Figure 2. Technology-specific scores of the top 10 countries [89].

To sum up, there are some major socio-economic benefits of the application of solar energy technology, including job creation, trade balance, industrial development, human welfare improvements, climate change solutions, etc. By formulating relevant policies, the development of PV systems can be accelerated to extract maximum benefit and achieve SDGs.

7. Conclusions

In the face of escalating environmental challenges and the imperative to curtail greenhouse gas emissions, solar energy, particularly through PV technology, has emerged as a pivotal player in the global energy landscape. The trajectory of solar power from its nascent stages to the current era of advanced PV systems underscores a remarkable journey marked by technological innovation, efficiency improvements, and substantial cost reductions. The economic dynamics surrounding solar energy present a dual narrative. Developed economies, leveraging technological advancements, supportive policies, and heightened environmental consciousness, have established themselves as leaders of solar energy adoption. Simultaneously, developing nations find a unique opportunity in solar energy to meet burgeoning energy demands sustainably. With increasing affordability, policy support, and a commitment to sustainable development, these nations stand poised to significantly expand their solar energy capacities. China's ascendancy in renewable energy, particularly solar power, exemplifies a broader trend, with other nations like India and Pakistan actively contributing to the global shift. The socio-economic implications of solar energy deployment are substantial, ranging from job creation and industrial development to an enhanced quality of life. The declining costs of solar panels, as evidenced in countries like Kenya and India, enhance the attractiveness of solar energy as a competitive alternative to traditional sources. Solar energy transcends its role as a mere eco-friendly energy source; it emerges as a catalyst for economic and social progress on a global scale. As nations commit to sustainable practices, the transformative potential of solar power becomes evident, charting a course towards a cleaner, economically viable, and collaborative energy future. Projections affirming solar energy as the primary global electricity source by 2050 underscore its centrality in shaping a sustainable tomorrow. The journey of solar energy is not merely a technological evolution; it is a shift towards a more resilient, equitable, and environmentally conscious energy paradigm.

Author Contributions: Conceptualization, A.B. and I.G.P.; methodology, A.B.; software, A.B. and Y.H.K.; validation, A.B., I.G.P. and M.A.K.; formal analysis, A.B. and M.A.K.; investigation A.B. and M.A.K.; resources, A.B. and M.A.K.; writing—original draft preparation, A.B., I.G.P. and Y.H.K. writing—review and editing, A.B. and M.A.K.; visualization, A.B. and I.G.P. supervision I.G.P.; All authors have read and agreed to the published version of the manuscript.

Funding: The author Amal Bouich acknowledges MCIN for funding support through Margarita Salas Fellowship (MCIN/AEI/10.13039/501100011033). This work has been funded by the Ministerio de Ciencia e Innovación (Spain) and by the Spanish Agencia Estatal de Investigación through projects BESTMAT PID2019-107137RB-C21/AEI/10.13039/501100011033 and PID2019-107137RB-C22/AEI/10.13039/501100011033 and by the ERDF under the funding project "A way of making Europe".

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Azuatalam, D.; Paridari, K.; Ma, Y.; Förstl, M.; Chapman, A.C.; Verbič, G. Energy management of small-scale PV-battery systems: A systematic review considering practical implementation, computational requirements, quality of input data and battery degradation. *Renew. Sustain. Energy Rev.* **2019**, *112*, 555–570. [CrossRef]
2. Ceglia, F.; Esposito, P.; Marrasso, E.; Sasso, M. From smart energy community to smart energy municipalities: Literature review, agendas and pathways. *J. Clean. Prod.* **2020**, *254*, 120118. [CrossRef]
3. Fu, J.; Mao, X.; Siyal, A.A.; Liu, Y.; Ao, W.; Liu, G.; Dai, J. Pyrolysis of furfural residue pellets: Physicochemical characteristics of pyrolytic pellets and pyrolysis kinetics. *Renew. Energy* **2021**, *179*, 2136–2146. [CrossRef]
4. Rehmani, A.M.; Kazmi, S.A.A.; Altamimi, A.; Khan, Z.A.; Awais, M. Techno-Economic-Environmental Assessment of an Isolated Rural Micro-Grid from a Mid-Career Repowering Perspective. *Sustainability* **2023**, *15*, 2137. [CrossRef]
5. IEA Renewables 2019: Analysis and Forecast to 2024. 2019. Available online: https://www.iea.org/reports/renewables-2019 (accessed on 19 September 2023).
6. Kihlström, V.; Elbe, J. Constructing Markets for Solar Energy—A Review of Literature about Market Barriers and Government Responses. *Sustainability* **2021**, *13*, 3273. [CrossRef]
7. International Energy Agency. *Electricity Market Report 2023*; International Energy Agency: Paris, France, 2023.

8. Goodwin, N.; Harris, J.; Nelson, J.; Roach, B.; Torras, M. *Principles of Economics in Context*; Routledge: Milton Park, UK, 2015; ISBN 9781317462170.
9. Dwivedi, Y.K.; Ismagilova, E.; Hughes, D.L.; Carlson, J.; Filieri, R.; Jacobson, J.; Jain, V.; Karjaluoto, H.; Kefi, H.; Krishen, A.S.; et al. Setting the future of digital and social media marketing research: Perspectives and research propositions. *Int. J. Inf. Manag.* **2021**, *59*, 102168. [CrossRef]
10. Geroski, P.; Gilbert, R.J.; Jacquemin, A. *Barriers to Entry and Strategic Competition*, 1st ed.; Harwood Academic Publishers: London, UK, 1990.
11. Constantine, C. Economic structures, institutions and economic performance. *J. Econ. Struct.* **2017**, *6*, 2. [CrossRef]
12. Beckert, J. The social order of markets. *Theory Soc.* **2009**, *38*, 245–269. [CrossRef]
13. Kogler, D.F.; Evenhuis, E.; Giuliani, E.; Martin, R.; Uyarra, E.; Boschma, R. Re-imagining evolutionary economic geography. *Cambridge J. Reg. Econ. Soc.* **2023**, *20*, rsad029. [CrossRef]
14. Murzakulova, A.; Kuznetsova, I.; Mogilevskii, R. *Has Immobility Been Left Behind in Migration Regulatory Infrastructures?* John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2023. [CrossRef]
15. Dabić, M.; Huck, N.; Meissner, D.; Zaichenko, S. *Opening the Black Box: Measuring the Performance of Research Organization*; IEEE: Piscataway, NJ, USA, 2023; pp. 1–25. [CrossRef]
16. Stampfl, R.; Fischer, J.; Palkovits-Rauter, S. Forms of Knowledge Transfer in IT Project Management. *MAP Soc. Sci.* **2023**, *4*, 53–66. [CrossRef]
17. Farag, M.; Zaki, C. *On the Economic and Political Determinants of Trade in Natural Gas*; Wiley & Sons, Inc.: Hoboken, NJ, USA, 2023. [CrossRef]
18. Busygina, I.; Filippov, M. *Non-Democratic Federalism and Decentralization in Post-Soviet States*; Routledge: London, UK, 2023; ISBN 9781003267508.
19. Yadav, N.; Upadhyay, R.K. Global Effect of Climate Change on Seasonal Cycles, Vector Population and Rising Challenges of Communicable Diseases: A Review. *J. Atmos. Sci. Res.* **2023**, *6*. [CrossRef]
20. Fitriningrum, A.; Pulungan, A.H.; Darusidhi, P. Government, state-owned enterprise, and liberalization of universal postal obligation services. *J. Policy Stud.* **2023**, *38*, 25–40. [CrossRef]
21. Ekakitie, E.S.; Stella, U.C.; Akparobi, N.J. Price Volatility and Market Integration: The Case of Selected Cereal Merchandizing In South-South, Nigeria. *Cent. Eur. Manag. J.* **2023**, *31*, 410–423. [CrossRef]
22. Fleury, S.; Lanzara, A.; Pinho, C.; Pernasetti, F.; Lobato, L.; Burlandy, L.; Senna, M.; Teodoro, R. *Authoritarian Populism, De-Democratization, and Social Policy Dismantling: Lessons from Brazil*; Springer: Berlin/Heidelberg, Germany, 2023; pp. 217–240.
23. Helwig, N.E.; Hong, S.; Hsiao-wecksler, E.T. Towards Carbon-Free Electricity: A Comprehensive Flow-Based Framework for Power Grid Carbon Accounting and Decarbonization. *arXiv* **2023**, arXiv:2308.03268. [CrossRef]
24. Xia, J.; Li, H.; He, Z. The Effect of Blockchain Technology on Supply Chain Collaboration: A Case Study of Lenovo. *Systems* **2023**, *11*, 299. [CrossRef]
25. Bórawski, P.; Holden, L.; Bełdycka-Bórawska, A. Perspectives of photovoltaic energy market development in the european union. *Energy* **2023**, *270*, 126804. [CrossRef]
26. Wen, D.; Gao, W. Impact of Renewable Energy Policies on Solar Photovoltaic Energy: Comparison of China, Germany, Japan, and the United States of America. In *Distributed Energy Resources*; Springer: Cham, Switzerland, 2023; ISBN 9783031210969.
27. Rathore, A.S.; Sarin, D. *What Should Next-Generation Analytical Platforms for Biopharmaceutical Production Look Like?* Elsevier: Amsterdam, The Netherlands, 2023. [CrossRef]
28. Solar Energy Insights Top 50 Countries That Use the Most Solar Power as a Percentage of Their Total Consumption. 2022. Available online: https://solarpower.guide/solar-energy-insights/countries-solar-power-consumption (accessed on 19 September 2023).
29. First Solar Website. Available online: https://www.firstsolar.com/ (accessed on 19 September 2023).
30. Qi, X.; Song, C.; Zhang, W.; Shi, Y.; Gao, Y.; Liu, H.; Chen, R.; Shang, L.; Tan, H.; Tan, F.; et al. Bidirectional Targeted Therapy Enables Efficient, Stable, and Eco-Friendly Perovskite Solar Cells. *Adv. Funct. Mater.* **2023**, *33*, 2214714. [CrossRef]
31. Shah, N.; Shah, A.A.; Leung, P.K.; Khan, S.; Sun, K.; Zhu, X.; Liao, Q. A Review of Third Generation Solar Cells. *Processes* **2023**, *11*, 1852. [CrossRef]
32. Al-Ezzi, A.S.; Ansari, M.N.M. Photovoltaic Solar Cells: A Review. *Appl. Syst. Innov.* **2022**, *5*, 67. [CrossRef]
33. Bouich, A. Study and Characterization of Hybrid Perovskites and Copper-Indium-Gallium Selenide Thin Films for Tandem Solar Cells. Ph.D. Thesis, Universitat Politècnica de València, Valencia, Spain, 2021.
34. Bouich, A.; Marí-Guaita, J.; Baig, F.; Hameed Khattak, Y.; Soucase, B.M.; Palacios, P. Investigation of the Surface Coating, Humidity Degradation, and Recovery of Perovskite Film Phase for Solar-Cell Applications. *Nanomaterials* **2022**, *12*, 3027. [CrossRef]
35. Aka, A.H.; Bouich, A.; Aka, B.; Soucase, B.M. Synthesis and characterization of kesterite Cu2ZnSn (SxSe1-x) 4 thin films with low-cost for efficient solar cells. *Results Opt.* **2023**, *13*, 100507. [CrossRef]
36. Huang, J.; He, S.; Zhang, W.; Saparbaev, A.; Wang, Y.; Gao, Y.; Shang, L.; Dong, G.; Nurumbetova, L.; Yue, G.; et al. Efficient and Stable All-Inorganic CsPbIBr 2 Perovskite Solar Cells Enabled by Dynamic Vacuum-Assisted Low-Temperature Engineering. *Sol. RRL* **2022**, *6*, 2100839. [CrossRef]
37. Wu, S.; Liu, L.; Zhang, B.; Gao, Y.; Shang, L.; He, S.; Li, S.; Zhang, P.; Chen, S.; Wang, Y. Multifunctional Two-Dimensional Benzodifuran-Based Polymer for Eco-Friendly Perovskite Solar Cells Featuring High Stability. *ACS Appl. Mater. Interfaces* **2022**, *14*, 41389–41399. [CrossRef] [PubMed]

38. Bouich, A.; Torres, J.C.; Chfii, H.; Marí-Guaita, J.; Khattak, Y.H.; Baig, F.; Soucase, B.M.; Palacios, P. Delafossite as hole transport layer a new pathway for efficient perovskite-based solar sells: Insight from experimental, DFT and numerical analysis. *Solar Energy* **2023**, *250*, 18–32. [CrossRef]
39. Bouazizi, S.; Bouich, A.; Tlili, W.; Amlouk, M.; Omri, A.; Soucase, B.M. Methylammonium lead triiodide perovskite-based solar cells efficiency: Insight from experimental and simulation. *J. Mol. Graph. Model.* **2023**, *122*, 108458. [CrossRef]
40. Doumbia, Y.; Bouich, A.; Soucase, B.M.; Soro, D. Towards Stable Free Lead Mixed Halide Perovskite Thin Films on FTO-Coated Glass Substrate. *JOM* **2023**, *75*, 4479–4484. [CrossRef]
41. Gao, Y.; Xiao, Z.; Cui, M.; Saidaminov, M.I.; Tan, F.; Shang, L.; Li, W.; Qin, C.; Ding, L. *Asymmetric Π-Bridge Engineering Enables High-Permittivity Benzo[1,2-B:4,5-B′]Difuran-Conjugated Polymer for Efficient Organic Solar Cells*; Wiley & Sons, Inc.: Hoboken, NJ, USA, 2023. [CrossRef]
42. Liu, S.; Wei, C.; Wang, H.; Yang, W.; Zhang, J.; Wang, Z.; Zhao, W.; Lee, P.S.; Cai, G. Processable nanoarchitectonics of two-dimensional metallo-supramolecular polymer for electrochromic energy storage devices with high coloration efficiency and stability. *Nano Energy* **2023**, *110*, 108337. [CrossRef]
43. Gao, Y.; Shen, Z.; Tan, F.; Yue, G.; Liu, R.; Wang, Z.; Qu, S.; Wang, Z.; Zhang, W. Novel benzo[1,2-b:4,5-b']difuran-based copolymer enables efficient polymer solar cells with small energy loss and high VOC. *Nano Energy* **2020**, *76*, 104964. [CrossRef]
44. Bouich, A.; Torres, J.C.; Khattak, Y.H.; Baig, F.; Marí-Guaita, J.; Soucase, B.M.; Mendez-Blas, A.; Palacios, P. Bright future by controlling α/δ phase junction of formamidinium lead iodide doped by imidazolium for solar cells: Insight from experimental, DFT calculations and SCAPS simulation. *Surf. Interfaces* **2023**, *40*, 103159. [CrossRef]
45. Koné, K.E.; Bouich, A.; Soucase, B.M.; Soro, D. Optical and structural investigation of methylammonium lead perovskite Mixed Halide (I, Br, and Cl) on spin-coated zinc oxide. *Results Opt.* **2023**, *13*, 100531. [CrossRef]
46. Marques Lameirinhas, R.A.; Torres, J.P.N.; de Melo Cunha, J.P. A Photovoltaic Technology Review: History, Fundamentals and Applications. *Energies* **2022**, *15*, 1823. [CrossRef]
47. Garnett, E.C.; Ehrler, B.; Polman, A.; Alarcon-Llado, E. Photonics for Photovoltaics: Advances and Opportunities. *ACS Photonics* **2021**, *8*, 61–70. [CrossRef] [PubMed]
48. Ašmontas, S.; Mujahid, M. Recent Progress in Perovskite Tandem Solar Cells. *Nanomaterials* **2023**, *13*, 1886. [CrossRef] [PubMed]
49. Akhil, S.; Akash, S.; Pasha, A.; Kulkarni, B.; Jalalah, M.; Alsaiari, M.; Harraz, F.A.; Balakrishna, R.G. Review on perovskite silicon tandem solar cells: Status and prospects 2T, 3T and 4T for real world conditions. *Mater. Des.* **2021**, *211*, 110138. [CrossRef]
50. Peters, I.M.; Rodriguez Gallegos, C.D.; Sofia, S.E.; Buonassisi, T. The Value of Efficiency in Photovoltaics. *Joule* **2019**, *3*, 2732–2747. [CrossRef]
51. Bhat, A.; Dhamaniya, B.P.; Chhillar, P.; Korukonda, T.B.; Rawat, G.; Pathak, S.K. Analysing the prospects of perovskite solar cells within the purview of recent scientific advancements. *Crystals* **2018**, *8*, 242. [CrossRef]
52. Elsmani, M.I.; Fatima, N.; Jallorina, M.P.A.; Sepeai, S.; Su'ait, M.S.; Ahmad Ludin, N.; Mat Teridi, M.A.; Sopian, K.; Ibrahim, M.A. Recent Issues and Configuration Factors in Perovskite-Silicon Tandem Solar Cells towards Large Scaling Production. *Nanomaterials* **2021**, *11*, 3186. [CrossRef]
53. Wang, F.; Harindintwali, J.D.; Yuan, Z.; Wang, M.; Wang, F.; Li, S.; Yin, Z.; Huang, L.; Fu, Y.; Li, L.; et al. Technologies and perspectives for achieving carbon neutrality. *Innovation* **2021**, *2*, 100180. [CrossRef]
54. Irfan, M.; Zhao, Z.-Y.; Ahmad, M.; Mukeshimana, M. Solar Energy Development in Pakistan: Barriers and Policy Recommendations. *Sustainability* **2019**, *11*, 1206. [CrossRef]
55. Izam, N.S.M.N.; Itam, Z.; Sing, W.L.; Syamsir, A. Sustainable Development Perspectives of Solar Energy Technologies with Focus on Solar Photovoltaic—A Review. *Energies* **2022**, *15*, 2790. [CrossRef]
56. Research Dive Solar Energy Market. 2021. Available online: https://www.researchdive.com/3874/solar-energy-market (accessed on 19 September 2023).
57. Guchhait, R.; Sarkar, B. Increasing Growth of Renewable Energy: A State of Art. *Energies* **2023**, *16*, 2665. [CrossRef]
58. UN. *REN21 Renewables 2022 Global Status Report*; UN: Paris, France, 2022.
59. Das, S.S.; Kumar, J.; Dawn, S.; Salata, F. Existing Stature and Possible Outlook of Renewable Power in Comprehensive Electricity Market. *Processes* **2023**, *11*, 1849. [CrossRef]
60. International Renewable Energy Agency (IRENA). *World Adds Record New Renewable Energy Capacity in 2020*; IRENA: Abu Dhabi, United Arab Emirates, 2021.
61. International Energy Agency. *Renewable Electricity*; International Energy Agency: Paris, France, 2022.
62. Abdelrazik, M.K.; Abdelaziz, S.E.; Hassan, M.F.; Hatem, T.M. Climate action: Prospects of solar energy in Africa. *Energy Rep.* **2022**, *8*, 11363–11377. [CrossRef]
63. Painuly, J.P.; Wohlgemuth, N. Renewable energy technologies: Barriers and policy implications. In *Renewable-Energy-Driven Future*; Elsevier: Amsterdam, The Netherlands, 2021; pp. 539–562.
64. Xin, Y.; Bin Dost, M.K.; Akram, H.; Watto, W.A. Analyzing Pakistan's Renewable Energy Potential: A Review of the Country's Energy Policy, Its Challenges, and Recommendations. *Sustainability* **2022**, *14*, 16123. [CrossRef]
65. Takase, M.; Aboah, M.; Kipkoech, R. A review on renewable energy potentials and energy usage statistics in Ghana. *Fuel Commun.* **2022**, *11*, 100065. [CrossRef]
66. Raina, G.; Sinha, S. Outlook on the Indian scenario of solar energy strategies: Policies and challenges. *Energy Strateg. Rev.* **2019**, *24*, 331–341. [CrossRef]

67. KhareSaxena, A.; Saxena, S.; Sudhakar, K. *Solar Energy Policy of India: An Overview*; IEEE: Piscataway, NJ, USA, 2020. [CrossRef]
68. Ichord, R.F. Transforming the Power Sector in Developing Countries: Geopolitics, Poverty, and Climate Change in Pakistan. 2020. Available online: http://ebooksnspp.punjab.gov.pk:8080/jspui/handle/nspp/562 (accessed on 1 September 2023).
69. Kumar, C.R.; Majid, M.A. Renewable energy for sustainable development in India: Current status, future prospects, challenges, employment, and investment opportunities. *Energy. Sustain. Soc.* **2020**, *10*, 2. [CrossRef]
70. International Renewable Energy Agency (IRENA). *Record Growth in Renewables Achieved Despite Energy Crisis*; IRENA: Abu Dhabi, United Arab Emirates, 2023.
71. Forum, W.E. Fostering Effective Energy Transition 2023 Edition Insight Report. 2023. Available online: https://www.weforum.org/reports/fostering-effective-energy-transition-2023?gclid=Cj0KCQjwhL6pBhDjARIsAGx8D58MJj_Q7YrGHyE1YAs28rbYjsBP9m9nnXXHssh_-tDbAy_1ItselT8aAsrKEALw_wcB (accessed on 19 September 2023).
72. International Renewable Energy Agency (IRENA). *World Energy Transitions Outlook 2022*; IRENA: Abu Dhabi, United Arab Emirates, 2022.
73. European Commission. *In Focus: Reducing the EU's Dependence on Imported Fossil Fuels*; European Commission: Brussels, Belgium, 2022.
74. European Commission. *CEF Energy: Contributing to the Security of Energy Supply in the EU*; European Commission: Brussels, Belgium, 2022.
75. Berns, M.; Herhold, P.; Lesser, R.; Nielsen, J.; Pieper, C.; Akiike, R.; Porsborg-Smith, A.; Tobing, L.; Brijs, T.; Jones, E.R.; et al. A Blueprint for the Energy Transition. 2023. Available online: https://www.bcg.com/industries/energy/energy-transition/blueprint (accessed on 19 September 2023).
76. Jacobo, J.T. Spain to Fast-Track Solar PV Permits in Bid to Tackle Energy Crisis. 2022. Available online: https://www.pv-tech.org/spain-to-fast-track-solar-pv-permits-in-bid-to-tackle-energy-crisis/ (accessed on 19 September 2023).
77. Reve Iberdrola Completes Its First Hybrid Wind and Solar Plant in Spain. 2023. Available online: https://www.iberdrola.com/press-room/news/detail/iberdrola-completes-construction-spain-first-hybrid-wind-solar-plant (accessed on 19 September 2023).
78. European Commission. *Analysis of the Offshore Wind Tender Results in Japan*; European Commission: Brussels, Belgium, 2022.
79. International Energy Agency. *Renewable Power's Growth is Being Turbocharged as Countries Seek to Strengthen Energy Security*; International Energy Agency: Paris, France, 2022.
80. Durganjali, C.S.; Bethanabhotla, S.; Kasina, S.; Radhika, D.S. Recent Developments and Future Advancements in Solar Panels Technology. *J. Phys. Conf. Ser.* **2020**, *1495*, 012018. [CrossRef]
81. Maka, A.O.M.; Alabid, J.M. Solar energy technology and its roles in sustainable development. *Clean Energy* **2022**, *6*, 476–483. [CrossRef]
82. Zhang, P.; Tilley, M.; Bai, G.; Harmer, S.; Duke, S.; Seabourn, B.W.; Zhang, G. Effect of wheat quality traits and glutenin composition on tortilla quality from the USDA Southern Regional Performance Nursery. *Cereal Chem.* **2021**, *98*, 1227–1237. [CrossRef]
83. Sánchez-Pantoja, N.; Vidal, R.; Pastor, M.C. Aesthetic impact of solar energy systems. *Renew. Sustain. Energy Rev.* **2018**, *98*, 227–238. [CrossRef]
84. Al Kurdi, B.; Alshurideh, M.; Alnaser, A. The impact of employee satisfaction on customer satisfaction: Theoretical and empirical underpinning. *Manag. Sci. Lett.* **2020**, *10*, 3561–3570. [CrossRef]
85. Ward, E.M.; Germolec, D.; Kogevinas, M.; McCormick, D.; Vermeulen, R.; Anisimov, V.N.; Aronson, K.J.; Bhatti, P.; Cocco, P.; Costa, G.; et al. Carcinogenicity of night shift work. *Lancet Oncol.* **2019**, *20*, 1058–1059. [CrossRef]
86. Liu, Y.; Kumar, M.; Katul, G.G.; Porporato, A. Reduced resilience as a potential early warning signal of forest mortality. In Proceedings of the Ecological Society of America Annual Meeting, New Orleans, LA, USA, 5–10 August 2018.
87. Obaideen, K.; Shehata, N.; Sayed, E.T.; Abdelkareem, M.A.; Mahmoud, M.S.; Olabi, A.G. The role of wastewater treatment in achieving sustainable development goals (SDGs) and sustainability guideline. *Energy Nexus* **2022**, *7*, 100112. [CrossRef]
88. National Renewable Energy Laboratory (NREL). *Solar Photovoltaic Technology Basics*; National Renewable Energy Laboratory (NREL): Golden, CO, USA, 2021.
89. Bhuiyan, M.A.; Zhang, Q.; Khare, V.; Mikhaylov, A.; Pinter, G.; Huang, X. Renewable energy consumption and economic growth nexus—A systematic literature review. *Front. Environ. Sci.* **2022**, *10*, 878394. [CrossRef]