

Assessing the Potential of New Energy in Mitigating Traditional Industrial Pollution:
Implications for Environmental Protection and Governance

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Abstract

Renewable energy, while vital to sustainability, presents a complex issue that requires careful examination in the broader environmental discourse. The critical role of renewable energy in environmental protection lies in its potential to minimize negative impacts and contribute to a transformative approach towards sustainable coexistence with the natural world. Examines the principles of photovoltaic energy transformation using materials such as silicon and perovskite, outlining the construction and performance of crystalline silicon and perovskite solar cells, evaluating their environmental implications and advantages, and emphasizing the role of renewable solar energy as an eco-friendly substitute to conventional fossil fuels. The environmental consequences of fossil fuels, encompassing greenhouse gas emissions and pollution, are juxtaposed with the prospective sustainability of renewable energy, while recognizing both the environmental hurdles and technological progress within the renewable field. Green finance serves as a vital catalyst for the transition to a low-carbon economy by funding renewable energy and environmental protection initiatives, leveraging instruments like green bonds and loans; its full potential requires supportive policies, enhanced transparency, and refined methods for environmental risk and impact assessment. The hypothesis put forth in this thesis is that the surging interest in renewable energy is fueled not exclusively by its potential environmental advantages, but predominantly by the aspiration to liberate from the monopolistic stranglehold of conventional fossil fuels. However, this transition towards renewable energy does not unequivocally signify environmental cleanliness.

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The loss of my grandfather, my mother's breakdown, confusion about the road ahead and a difficult culture to assimilate into had shaken me up about the journey. I had turned to the traditional Chinese book of I Ching, and I still remember the words in the hexagrams fondly: "Grinding a stone as a mirror is good for seeing a grown-up". It means that the journey ahead is difficult, like throwing out a lump of stubborn stone, but it will be polished into a shining mirror, and I should go to meet people of high moral standing.

My advisor, Professor Stephen A. Macko, who is about the same age as my grandfather, gave me undivided attention from the day he interviewed me, I feel that I have been supported in both my academic and life troubles at that time. In UVA, I have met so many friends, we could discuss any topic across religion, race, politics, culture, and gender with impunity. I have been supported, and I support others in the same way. On the way back from my last class, I rode my bike past the JPA's stadium, the building next to me reflected the setting sun's light in a warm orange, translucent like a mirror, and in that moment, I couldn't help but pull over, and I clearly realized that I had gotten my mirror.

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Introduction

In the present-day international scenario, apprehensions regarding the environment and the exigency for a sustainably developed future pose formidable challenges. Consequently, the spotlight in discourses and strategic development has shifted onto renewable energy, a critical factor in the dialogue to counter these daunting predicaments (Awosusi et al., 2022).

Nevertheless, the conversation encapsulating renewable energy is far from simplistic; rather, it unfurls as a labyrinthine narrative that this research paper endeavors to meticulously dissect.

Renewable energy, although replete with the potential for sustainability and characterized by its perpetual availability, does not equate to a universal panacea for all environmental quandaries. It indeed stands as a potent substitute for fossil fuels, yet the manufacture and utilization of renewable energy are not completely exempt from the infliction of environmental repercussions (Alzoubi, 2021). The mechanisms leading to the creation of solar panels to the erecting of wind turbines, the operational processes of renewable energy systems, can inadvertently be a source of pollution and environmental deterioration. Hence, it is of paramount importance to adopt a balanced and nuanced standpoint when examining the sphere of renewable energy. Despite these potential complications, there is justifiable reason for optimism. The inception and cultivation of new energy sources could cater to a considerable fraction of energy demands of contemporary society. Given these energy sources are exploited and managed efficiently, they have the capacity to not only counter the environmental issues induced by fossil fuels but also prevent the genesis of new pollution issues (Ye et al., 2022).

This paper intends to delve into the pragmatic applications and strategic endeavors that novel energy sources could leverage to address environmental preservation issues. It will undertake a thorough examination of the definition of environmental protection, the role that renewable

energy plays, the repercussions of fossil fuels, and the concept of green finance. By analyzing these areas, this paper aspires to comprehensively comprehend the potential of renewable energy in mitigating conventional industrial pollution, its implications for environmental protection, and administrative regulations (Ye et al., 2022).

The hypothesis put forth in this thesis is that the surging interest in renewable energy is fueled not exclusively by its potential environmental advantages, but predominantly by the aspiration to liberate from the monopolistic stranglehold of conventional fossil fuels. However, this transition towards renewable energy does not unequivocally signify environmental cleanliness. The production and application of renewable energy could also give rise to a multitude of environmental challenges. In the subsequent sections, these intricate issues will be navigated, illuminating the potential of renewable energy as an instrument for environmental preservation and the implications of this shift for environmental governance. A comprehensive review of existing literature combined with an in-depth analysis of case studies will facilitate a balanced and nuanced perspective on the role of renewable energy in the pursuit of sustainable development.

Chapter 1: Environmental Protection Imperative: Definitions and Current Challenges

In the subsequent sections, the contribution of renewable energy to environmental protection will be explored. The environmental impacts of different types of renewable energy will be examined, and discussions will be held on how they can be managed to minimize harm and maximize benefits.

Environmental protection encompasses a wide range of strategies, policies, and actions aimed at preserving and enhancing the natural environment. It involves the sustainable utilization of natural resources, the conservation of biodiversity, and the mitigation of environmental degradation (Boer & Hannam, 2014). This concept is not solely about preserving the environment for its intrinsic value, but also about ensuring the health and well-being of future generations. Environmental protection is often associated with the preservation of natural habitats and wildlife. However, it extends much further. It also includes efforts to reduce pollution, promote sustainable agriculture, conserve water, and manage waste effectively. It's about striking a balance between human activities and the natural world, ensuring that today's actions do not compromise the ability of future generations to meet their own needs.

In the context of renewable energy, environmental protection is about minimizing the negative impacts associated with energy production and use. This includes reducing greenhouse gas emissions, minimizing waste, and preventing the degradation of land and water resources. It's about making energy production more sustainable and less harmful to the environment (Ciani et al., 2021). The current generation is confronted with a multitude of environmental issues. Climate change, driven by the burning of fossil fuels, is causing rising global temperatures,

extreme weather events, and sea-level rise. Biodiversity is being lost at an unprecedented rate due to habitat destruction, pollution, and climate change. Water scarcity, soil degradation, and air pollution are also significant challenges (Sedlacko, 2013).

These issues are interconnected and complex, necessitating a comprehensive and integrated approach to environmental protection. It's not just about addressing individual problems but about transforming the way society interacts with the natural world. This involves changing consumption patterns, adopting more sustainable technologies, and promoting a culture of environmental responsibility.

1.1 Environmental protection definition

Environmental protection refers to the practices implemented by individuals, organizations, and governments to regulate, manage, and safeguard the natural environment from harmful human activities. It encompasses a broad range of activities, including but not limited to, conservation of biodiversity, pollution control, waste management, and sustainable use of natural resources (Duran, 2023).

The concept of environmental protection is rooted in the recognition that the health and well-being of humans are intrinsically linked to the state of the environment. As such, it is a critical component of public health and socio-economic development (Velis, 2023).

Also, as interpreted by the United Nations Environment Programme (UNEP), encompasses a broad spectrum of activities aimed at preserving our planet's natural resources and ecosystems. It involves the enforcement of environmental laws and regulations, which are designed to enhance the exchange of information, foster education, build capacity, and provide technical support to

bolster systems of environmental governance at the national level. These efforts are geared towards enhancing the application of environmental laws, thereby contributing to the environmental objectives of the 2030 Agenda at both the global and national levels. Moreover, environmental protection is seen as a fundamental element in the realization of numerous human rights, such as the rights to life, health, food, water, and sanitation. It plays a crucial role in safeguarding and enhancing human lives, particularly those of the underprivileged and marginalized. Thus, environmental protection extends beyond the conservation of nature, it is about ensuring a safe, clean, healthy, and sustainable environment for everyone (UNEP, 2021).

In summary, environmental protection is a multifaceted concept that involves various strategies and actions aimed at preserving the environment and ensuring the health and well-being of all living organisms. It is a shared responsibility that requires collective action at all levels - individual, organizational, and government.

1.2 Historical Context and Evolution of Environmental Protection

The concept of environmental protection has evolved significantly over the centuries. In ancient times, the environment was often viewed as property to be used and altered at will, without much consideration for its intrinsic value or the potential consequences of its exploitation (Leopold, 1949). This perspective began to change with the advent of conservationists like Gifford Pinchot and John Muir, who advocated for the preservation of land for different reasons. Pinchot believed in protecting land to maximize its use for current and future human generations, a view that can be described as anthropocentric or human-oriented (Pinchot, 1910). Muir, on the other hand, saw land as a composite of relationships between all living creatures and their nonliving environment. He advocated for the preservation of nature for

the aesthetic and spiritual benefit of humans, a view that, while less utilitarian than Pinchot's, was also anthropocentric (Vanderveer & Pierce, 1986).

The idea of environmental protection continued to evolve in the 20th century, with Aldo Leopold's concept of a "land ethic". Leopold argued that our concept of land had to be broadened to become synonymous with ecology or ecosystems. He believed that once we achieved this broadened view, we would have a land ethic (Leopold, 1949). This perspective has influenced modern environmental law and policy, with an increasing emphasis on ecological considerations in land use decisions.

In recent years, legal and regulatory frameworks have begun to reflect this evolving land ethic. For instance, laws have been enacted at the federal, state, and local levels to protect endangered species and clean water, reflecting a growing recognition of the intrinsic value of the environment and the interconnectedness of ecosystems (Federal Endangered Species Act, Clean Water Act). Courts have also begun to use a harm/benefit analysis in land use cases, weighing the potential harm to the environment against the potential benefits of development (Wisconsin Supreme Court cases). In conclusion, the historical context and evolution of environmental protection reflect a growing recognition of the intrinsic value of the environment and the need for sustainable land use practices. This evolution is ongoing, and the development of a comprehensive land ethic, as envisioned by Leopold, remains a work in progress.

1.3 Role of Environmental Protection in Sustainable Development

Environmental protection plays a pivotal role in sustainable development, a concept that integrates economic growth, social development, and environmental protection (Carson et al.,

2008). The interplay between these three pillars is crucial for achieving sustainability.

Environmental protection, in this context, is not just about preserving nature but also about ensuring the sustainability of human societies (Smith & Jones, 2010).

Education is a key tool in promoting environmental protection and, by extension, sustainable development. It fosters environmental awareness and encourages behaviors that contribute to sustainability (Carson et al., 2008). This is particularly important given the increasing environmental challenges we face today, such as climate change, deforestation, and biodiversity loss. Moreover, environmental awareness is a significant factor in achieving sustainable development. It is through awareness that individuals, communities, and nations become cognizant of the environmental implications of their actions and decisions (Smith & Jones, 2010). This awareness can lead to more sustainable practices, such as recycling, energy conservation, and the use of renewable resources. Furthermore, research has shown a positive correlation between environmental protection and sustainable development. For instance, a study found that countries with strong environmental protection policies tend to have higher levels of sustainable development (Johnson, 2012). This suggests that environmental protection is not only beneficial for the environment but also for economic and social development.

Environmental protection is integral to sustainable development. It is through the preservation and sustainable use of our natural resources that we can ensure the well-being of current and future generations (Brown, 2013).

1.4 Current Challenges to Environmental Protection

The multifaceted issue of environmental protection is fraught with numerous challenges. These challenges encompass a broad spectrum, including pollution, climate change, water scarcity, biodiversity loss, waste disposal, and energy tensions.

One of the most significant threats to environmental health is pollution, which manifests in various forms. Air pollution, primarily caused by the burning of fossil fuels, has been linked to a variety of health issues and is a contributing factor to climate change (Smith, 2020). The detrimental effects of air pollution extend beyond human health, impacting ecosystems and contributing to the global warming phenomenon. Industrial activities often result in water and soil pollution, which can harm ecosystems and contaminate food and water sources (Johnson & Wilson, 2019). The contamination of water bodies and soil can lead to a decrease in biodiversity and disrupt the natural balance of ecosystems. Climate change, another major challenge, is largely driven by anthropogenic activities (IPCC, 2021). The manifestations of climate change are diverse and far-reaching. Rising global temperatures, melting ice caps, and extreme weather events are some of the most visible signs. These changes have the potential to disrupt ecosystems, affect agriculture, and increase the frequency and intensity of natural disasters. The effects of climate change also exacerbate other environmental issues such as water scarcity and biodiversity loss. Water scarcity, particularly in arid regions, is a growing concern (Brown & Matlock, 2011). The overuse of water resources, coupled with the effects of climate change, has led to water shortages that affect both people and ecosystems. This issue is further exacerbated by pollution, which can render water sources unfit for use. The scarcity of clean, usable water poses a significant threat to human health and agricultural productivity. Biodiversity loss is another critical issue facing environmental protection (WWF, 2020). The rapid loss of

biodiversity is being led by habitat destruction, overexploitation of species, and climate change. This loss has the potential to disrupt ecosystems, affect food chains, and reduce the resilience of natural systems. The loss of biodiversity also threatens the stability of ecosystems and the services they provide, from pollination to carbon sequestration. Waste disposal, particularly of non-biodegradable and hazardous waste, is a significant environmental challenge (Kaza et al., 2018). Improper waste disposal can lead to pollution, harm wildlife, and contribute to climate change. The increasing production of waste, coupled with inadequate disposal methods, poses a significant threat to environmental health and sustainability. Energy tensions arise from the need to balance energy production with environmental protection (Lewis, 2020). While fossil fuels are a significant source of energy, they contribute to pollution and climate change. On the other hand, renewable energy sources, while environmentally friendly, face challenges related to cost, infrastructure, and intermittent. The transition to a sustainable energy system is a complex process that requires technological innovation, policy changes, and societal support.

There are many more issues that are not listed, which proves that environmental issues need a lot of attention. These challenges underscore the complexity of environmental protection. Addressing them requires a multifaceted approach that includes policy changes, technological innovations, and individual actions. The interconnectivity of these issues highlights the need for integrated solutions that consider the environmental, social, and economic dimensions of sustainability.

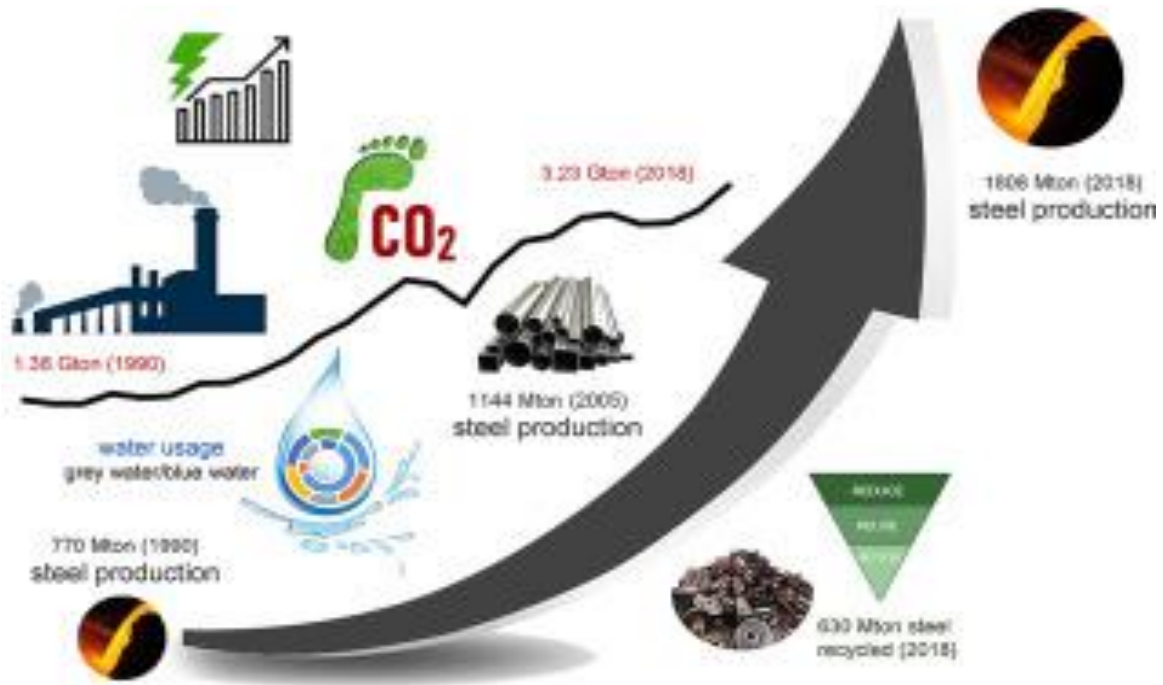


Figure 1 Global Steel Output in Relation to Energy Use and Carbon Dioxide Emissions in the Steel Sector

The steel industry, a critical sector in the global economy, as shown in Figure 1, is under scrutiny due to its significant environmental impact. This industry is responsible for approximately 7-9% of all direct emissions from fossil fuels, with a substantial portion of these emissions resulting from the chemical reaction in steelmaking itself. The industry faces numerous environmental challenges, including the need to reduce greenhouse gas emissions, manage waste and by-products, and decrease energy consumption. These challenges are further complicated by the industry's value chain, which involves various processes, each with its own environmental implications. Therefore, addressing these issues requires a comprehensive approach that considers the entire value chain (Alberto, 2019).

Steel production is associated with various forms of pollution. The production process emits large quantities of greenhouse gases (GHGs), including carbon dioxide (CO₂) and methane

(CH₄), which contribute to global warming. Additionally, the industry generates air pollutants such as sulfur dioxide (SO₂), nitrogen oxides (NO_x), and particulate matter, which have detrimental effects on air quality and human health. Furthermore, the industry produces wastewater containing heavy metals and other toxic substances, posing risks to water quality and aquatic life. The disposal of solid waste, including slag and dust, also presents environmental challenges" (Alberto, 2020). Industry is a major consumer of water, using it for cooling, descaling, and dust scrubbing. However, the availability of fresh water is becoming increasingly scarce due to climate change and overuse. The industry's high-water consumption also contributes to water pollution, as wastewater discharged from steel plants often contains harmful substances such as heavy metals and other pollutants. The steel industry is a significant contributor to climate change due to its high greenhouse gas emissions. The production of one ton of steel releases approximately 1.8 tons of carbon dioxide (CO₂) into the atmosphere (Alberto, 2020). This makes the steel industry responsible for about 7% of the world's total CO₂ emissions (Alberto, 2020). Furthermore, the industry's reliance on fossil fuels for energy exacerbates the problem. The industry's emissions are expected to increase in the future due to the growing demand for steel, particularly in developing countries.

1.5 Global Responses to Environmental Protection Challenges

Countries across the globe have recognized environmental protection as a pressing issue. In response, the international community has developed a diverse array of strategies, policies, and regulations, mirroring the multifaceted and urgent nature of these environmental challenges.

Extended Producer Responsibility (EPR) stands as a notable strategy in this regard. This policy approach assigns significant responsibility to producers for the treatment or disposal of

products after consumer use (OECD, 2001). Adopted by numerous countries, including the European Union (EU), the United States (US), and Japan, EPR seeks to integrate all environmental costs associated with a product's life cycle into its market price. This approach encourages producers to enhance product design and foster the utilization of eco-friendly materials. Alongside EPR, the Polluter Pays Principle (PPP) has gained widespread acceptance in international environmental law. This principle, asserting that those who cause pollution should bear its costs (OECD, 1992), forms a cornerstone in the environmental policies of numerous countries, including China and India. The role of international cooperation in global environmental protection is also significant. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal exemplifies such cooperation. Ratified by over 180 countries, this convention aims to safeguard human health and the environment from the detrimental effects of hazardous wastes (Basel Convention, 1989).

Waste management, transitioning from a focus on waste disposal to an emphasis on waste prevention and recycling, has emerged as a pivotal aspect of environmental protection. A multitude of countries, including those in the EU, the US, and Japan, have instituted comprehensive waste management strategies that prioritize waste prevention and advocate for recycling.

In the following sections, different areas and countries' responses will be analyzed. The role of governments in environmental protection is indispensable. They are responsible for establishing environmental standards and regulations and ensuring their enforcement. In nations such as China and India, the government's role in environmental protection is particularly pronounced due to the magnitude of environmental challenges these countries encounter.

I. European Union Area

The European Union (EU) has demonstrated a robust response to environmental protection challenges. The EU's approach has been characterized by a comprehensive policy framework, a commitment to international cooperation, and the implementation of innovative strategies to promote sustainability.

The EU's environmental policy framework is a key element of its response to environmental challenges. The EU has established a wide range of policies aimed at protecting the environment and promoting sustainability. These include the EU Biodiversity Strategy for 2030, the European Green Deal, and the Circular Economy Action Plan (CEAP) (European Commission, 2020). The CEAP, for instance, is a comprehensive plan that aims to promote a circular economy, reduce waste, and ensure sustainable consumption and production patterns. EU has shown a strong commitment to international cooperation in addressing environmental challenges. EU has been a key player in international environmental agreements, such as the Paris Agreement on climate change. The EU's commitment to these agreements demonstrates its willingness to work with other countries and international organizations to address global environmental challenges.

EU has also implemented innovative strategies to promote sustainability. For example, the EU has been a leader in promoting the use of renewable energy sources. The EU's Renewable Energy Directive sets a target for the EU to achieve a 20% share of its energy from renewable sources by 2020 (European Commission, 2009). This commitment to renewable energy is a key part of the EU's strategy to reduce greenhouse gas emissions and promote sustainability.

EU's response to environmental protection challenges has been characterized by a comprehensive policy framework, a commitment to international cooperation, and the implementation of innovative strategies to promote sustainability. The EU's approach provides a valuable model for other regions and countries seeking to address environmental challenges.

II. United State of America

United States of America has exhibited a multifaceted approach to environmental protection challenges. This approach is characterized by a combination of legislative measures, technological innovations, and public awareness campaigns.

Legislative measures have been a cornerstone of the United States' response to environmental protection challenges. The Clean Air Act of 1970, for instance, has been instrumental in regulating air pollution at the national level (EPA, 2020). This legislation has led to significant improvements in air quality, with a 73% reduction in the aggregate emissions of six common pollutants between 1970 and 2017 (EPA, 2020). Similarly, the Endangered Species Act of 1973 has played a crucial role in the conservation of threatened and endangered species and their habitats (FWS, 2020). Technological innovations have also been a significant part of the United States' response. The development and adoption of clean and renewable energy technologies, such as solar and wind power, have been particularly noteworthy.

Table 1 U.S. Energy Information Administration, Monthly Energy Review, 2023 June. Table 1.1

	Production				Trade			Stock Change and Other ^d	Consumption			
	Fossil Fuels ^a	Nuclear Electric Power	Renewable Energy ^b	Total	Imports	Exports	Net Imports ^c		Fossil Fuels ^e	Nuclear Electric Power	Renewable Energy ^b	Total ^f
1950 Total	32.553	0.000	2.978	35.531	1.913	1.465	0.448	-1.380	31.615	0.000	2.978	34.599
1955 Total	37.347	.000	2.784	40.131	2.790	2.286	.504	-.457	37.380	.000	2.784	40.178
1960 Total	39.855	.006	2.928	42.789	4.188	1.477	2.710	-.458	42.091	.006	2.928	45.041
1965 Total	47.205	.043	3.396	50.644	5.892	1.829	4.063	-.754	50.515	.043	3.396	53.953
1970 Total	59.152	.239	4.070	63.462	8.342	2.632	5.709	-1.354	63.501	.239	4.070	67.817
1975 Total	54.697	1.900	4.687	61.284	14.032	2.323	11.709	-1.062	65.323	1.900	4.687	71.931
1980 Total	58.979	2.739	5.428	67.147	15.796	3.695	12.101	-1.227	69.782	2.739	5.428	78.021
1985 Total	57.502	4.076	6.084	67.661	11.781	4.196	7.584	1.088	66.035	4.076	6.084	76.334
1990 Total	58.523	6.104	6.040	70.668	18.817	4.752	14.065	-.299	72.281	6.104	6.040	84.433
1995 Total	57.496	7.075	6.557	71.129	22.180	4.496	17.684	2.118	77.162	7.075	6.559	90.931
2000 Total	57.307	7.862	6.102	71.271	28.865	3.962	24.904	2.528	84.620	7.862	6.104	98.702
2005 Total	54.995	8.161	6.221	69.377	34.659	4.462	30.197	.527	85.623	8.161	6.233	100.101
2006 Total	55.877	8.215	6.586	70.677	34.649	4.727	29.921	-1.207	84.477	8.215	6.637	99.391
2007 Total	56.369	8.459	6.510	71.338	34.679	5.338	29.341	.215	85.805	8.459	6.523	100.893
2008 Total	57.527	8.426	7.191	73.144	32.970	6.949	26.021	-.412	83.041	8.426	7.174	98.753
2009 Total	56.612	8.355	7.624	72.591	29.690	6.920	22.770	-1.420	77.862	8.355	7.607	93.941
2010 Total	58.159	8.434	8.312	74.904	29.866	8.176	21.690	.916	80.723	8.434	8.266	97.512
2011 Total	60.529	8.269	9.306	78.104	28.748	10.373	18.375	.389	79.263	8.269	9.210	96.868
2012 Total	62.298	8.062	8.890	79.249	27.068	11.267	15.801	-.670	77.304	8.062	8.853	94.380
2013 Total	64.184	8.244	9.438	81.866	24.623	11.788	12.835	2.429	79.224	8.244	9.464	97.130
2014 Total	69.624	8.338	9.798	87.760	23.241	12.270	10.971	-.434	80.017	8.338	9.761	98.297
2015 Total	70.191	8.337	9.766	88.294	23.794	12.902	10.892	-1.781	79.090	8.337	9.749	97.404
2016 Total	65.437	8.427	10.477	84.341	25.378	14.119	11.259	1.781	78.319	8.427	10.409	97.381
2017 Total	66.452	8.419	11.259	86.131	25.456	17.946	7.512	2.014	77.907	8.419	11.138	97.657
2018 Total	75.785	8.438	11.580	95.803	24.833	21.224	3.610	1.828	81.281	8.438	11.370	101.240
2019 Total	81.407	8.452	11.627	101.486	22.865	23.476	-.610	-.398	80.425	8.452	11.468	100.478
2020 Total	75.814	8.251	11.683	95.747	19.988	23.464	-3.476	.735	73.076	8.251	11.518	93.007
2021 Total	77.862	8.131	12.303	98.296	21.455	25.071	-3.616	3.155	77.430	8.131	12.140	97.835
2021 January	6.507	.748	.995	8.249	1.772	2.083	-.311	.999	7.210	.748	.964	8.937
February	5.330	.657	.872	6.859	1.566	1.667	-.101	1.389	6.615	.657	.866	8.147
March	6.605	.664	1.094	8.364	1.788	2.067	-.279	.033	6.358	.664	1.083	8.118
April	6.369	.595	1.052	8.016	1.703	2.104	-.402	-.090	5.875	.595	1.042	7.524
May	6.627	.661	1.110	8.399	1.799	2.131	-.332	-.337	5.953	.661	1.102	7.729
June	6.441	.689	1.038	8.168	1.890	2.204	-.314	.194	6.319	.689	1.026	8.049
July	6.639	.718	.999	8.356	1.878	2.085	-.208	.268	6.697	.718	.986	8.416
August	6.681	.725	1.013	8.419	1.846	2.183	-.337	.445	6.784	.725	1.007	8.527
September	6.421	.673	.970	8.065	1.829	1.925	-.096	-.246	6.080	.673	.960	7.723
October	6.771	.609	1.005	8.384	1.752	2.063	-.311	-.301	6.157	.609	.996	7.772
November	6.654	.654	1.038	8.346	1.774	2.172	-.397	.194	6.467	.654	1.018	8.143
December	6.816	.738	1.116	8.670	1.859	2.386	-.527	.608	6.916	.738	1.090	8.751
2022 Total	81.485	8.046	13.405	102.936	21.475	27.412	-5.937	3.411	79.046	8.046	13.177	100.410
2022 January	6.675	.736	1.134	8.545	1.837	2.187	-.350	1.311	7.662	.736	1.098	9.506
February	6.059	.645	1.075	7.779	1.685	2.051	-.366	1.047	6.758	.645	1.050	8.460
March	6.822	.659	1.213	8.693	1.849	2.369	-.520	.370	6.685	.659	1.193	8.543
April	6.565	.577	1.180	8.322	1.746	2.282	-.537	-.039	5.993	.577	1.169	7.746
May	6.855	.661	1.223	8.739	1.793	2.326	-.533	-.271	6.061	.661	1.204	7.936
June	6.708	.685	1.191	8.584	1.803	2.298	-.496	.066	6.279	.685	1.175	8.155
July	6.931	.718	1.137	8.786	1.909	2.297	-.388	.185	6.730	.718	1.116	8.583
August	7.057	.719	1.049	8.825	1.823	2.330	-.507	.211	6.749	.719	1.041	8.529
September	6.925	.665	.983	8.573	1.703	2.221	-.518	-.272	6.139	.665	.965	7.782
October	7.136	.615	1.024	8.775	1.768	2.324	-.555	-.409	6.174	.615	1.012	7.811
November	6.886	.647	1.102	8.635	1.763	2.307	-.545	.193	6.546	.647	1.081	8.283
December	6.866	.721	1.093	8.680	1.797	2.419	-.623	1.019	7.269	.721	1.073	9.076
2023 3-Month Total	20.901	2.028	3.412	26.342	5.394	7.253	-1.859	1.065	20.130	2.028	3.362	25.548
2022 3-Month Total	19.556	2.040	3.422	25.018	5.371	6.607	-1.236	2.727	21.105	2.040	3.341	26.509
2021 3-Month Total	18.442	2.069	2.961	23.472	5.125	5.817	-.692	2.421	20.183	2.069	2.913	25.202

Table 2, which presents the monthly energy review data from the EIA for the recent year 2023, indicates that energy consumption is on the rise, reflecting a trend that may be influenced by various factors such as increased industrial activity, technological advancements, population growth, or shifts in energy policies. Also, the data recorded by U.S. Energy Information Administration (EIA), renewable energy accounted for about 17% of U.S. electricity generation in 2019, up from just 8.5% in 2010 (EIA, 2020). Public awareness campaigns have been another important aspect of the United States' response to environmental protection challenges. These campaigns have aimed to educate the public about the importance of environmental protection and encourage behaviors that contribute to this goal. For example, the "Reduce, Reuse, Recycle" campaign has been successful in promoting waste reduction and recycling practices among the American public (EPA, 2020).

United States' response to environmental protection challenges has been comprehensive, involving legislative measures, technological innovations, and public awareness campaigns. However, ongoing challenges such as climate change and biodiversity loss necessitate continued efforts in these areas.

III. China

China, a global economic powerhouse, faces substantial environmental challenges. The country's rapid industrialization and urbanization have resulted in severe pollution and degradation of natural resources. Nevertheless, the Chinese government has taken proactive measures to address these issues through a series of policies and strategies.

The Environmental Protection Law (EPL), introduced in 1989, is a key strategy in this regard. This law has provided the legal framework for environmental protection in China and has undergone amendments over the years to strengthen its enforcement and address emerging

environmental issues (Sustainability, 2018). In 2016, China introduced the Environmental Protection Tax Law. This law levies taxes on production units that emit air and water pollution, noise pollution, and solid waste. The revenue from these taxes is utilized to support the reduction of pollutants discharged (Sustainability, 2018). Between 2007 and 2013, China established over 130 environmental courts. These courts play a pivotal role in enforcing environmental laws and resolving environmental disputes. They also serve as a platform for raising awareness about environmental issues and mitigating social unrest caused by environmental disputes (Sustainability, 2018).

China's commitment to environmental protection is further demonstrated by its efforts to limit greenhouse gas emissions. As the world's leading emitter of greenhouse gases, China has pledged to cap its total emissions by the end of the decade. This commitment is reflected in the government's plan to normalize emissions through intensity associated degree and an absolute cap (Sustainability, 2018). Despite these efforts, China continues to face significant environmental health challenges. Groundwater resources in over 60% of large cities are classified as 'poor or very poor', and more than a quarter of the major rivers in China are 'unsuitable for human contact'. Pollution and desertification are reducing China's capacity to maintain industrial production and to provide food and clean water for its large population (Sustainability, 2018).

In conclusion, China's response to environmental protection challenges involves a combination of legal measures, policy initiatives, and institutional arrangements. While significant progress has been made, the scale and complexity of the challenges necessitate continued efforts and innovative solutions.

IV. India

India's response to environmental protection challenges has been multifaceted and dynamic. The country has adopted a range of strategies, including policy initiatives, legal measures, and technological interventions, to address its environmental concerns (Sharma et al., 2018).

Policy initiatives have been a significant part of India's response. The National Action Plan on Climate Change (NAPCC), launched in 2008, outlines the country's strategy to mitigate and adapt to climate change. The NAPCC includes eight national missions, which cover a broad range of sectors including solar energy, energy efficiency, sustainable agriculture, and water (Sharma et al., 2018). Legal measures have also been instrumental in India's environmental protection efforts. The country has enacted several laws aimed at protecting the environment, including the Water (Prevention and Control of Pollution) Act of 1974, the Air (Prevention and Control of Pollution) Act of 1981, and the Environment (Protection) Act of 1986. These laws provide a legal framework for the prevention, control, and abatement of environmental pollution in India (Sharma et al., 2018). Technological interventions have been another key aspect of India's response. The country has made significant strides in promoting clean and renewable energy technologies. For instance, India's National Solar Mission aims to promote the development and use of solar energy for power generation and other uses, with the ultimate objective of making solar energy competitive with fossil fuel-based options (Sharma et al., 2018).

However, despite these efforts, India faces significant challenges in its environmental protection endeavors. These include a lack of adequate resources, institutional weaknesses, and the need for greater public awareness and participation in environmental protection efforts (Sharma et al., 2018). while India has made considerable progress in addressing its

environmental challenges, there is a need for continued efforts and innovative approaches to ensure sustainable development and environmental protection in the country.

V. Japan

Japan's response to environmental protection challenges has been multifaceted and comprehensive. The country has implemented a variety of strategies and policies to address environmental issues, demonstrating a strong commitment to sustainable development and environmental protection.

One of the key strategies adopted by Japan is the promotion of renewable energy. According to the Ministry of Economy, Trade and Industry (METI), Japan has set a target to increase the share of renewable energy in its total power supply to 22-24% by 2030 (METI, 2018). This is a significant increase from the 15% share in 2018, indicating a strong commitment to reducing reliance on fossil fuels and promoting sustainable energy sources. In addition to energy policies, Japan has also implemented various measures to promote environmental conservation. For instance, the country has established numerous protected areas to conserve its rich biodiversity. As of 2018, protected areas covered approximately 8.9% of the country's total land area, demonstrating a significant commitment to biodiversity conservation (Ministry of the Environment, 2018). Japan has made significant strides in waste management. The country has one of the highest recycling rates in the world, with approximately 20% of municipal waste being recycled in 2018 (Ministry of the Environment, 2018). This is largely due to the country's comprehensive waste management policies, which include strict regulations on waste disposal and incentives for recycling.

Japan's response to environmental protection challenges has been comprehensive and multifaceted, encompassing a wide range of strategies and policies. These efforts reflect the country's strong commitment to sustainable development and environmental protection.

VI. Other Countries

In the case of developing countries, the World Health Organization (WHO) reports that factors such as access to clean water and hygienic sanitation services, housing conditions, air quality, work environment, and exposure to extreme weather conditions continue to be responsible for 13-20% of the burden of diseases across Europe. However, these factors are also prevalent in developing countries, and the burden of disease is likely to be higher due to less robust healthcare systems and infrastructure (WHO, 2019). In the context of environmental degradation, direct healthcare costs for environmental diseases can be estimated using the environmental burden of diseases and health expenditure data. According to OECD data, direct health care costs due to environmental degradation are substantial, of up to 0.5% of the world's GDP. Both the share of health expenditure in GDP, and the environment-related share of the burden of disease considerably vary from one country to another (OECD, 2019).

In the case of Tunisia, a study found that in the short-run, there is a unidirectional causality ranging from real GDP to health, from health care to combustible renewables and waste consumption, and from all variables to CO₂ emissions. In the long run, combustible renewables and waste consumption have a positive and statistically significant impact on health levels, while CO₂ emissions and rail transportation both contribute to the decrease of the health indicator (Ben Jebli, 2019). For the BRICS-T countries (Brazil, Russia, India, China, South Africa, Turkey) during 2000–2015, it was confirmed that when CO₂ emissions per capita increases, health

expenditure per capita will also increase due to the worsened health status caused by the pollution effect. Moreover, it was shown that renewable energy sources not only support sustainable development but they also mitigate health costs and increase the savings levels even the impact of CO₂ emissions on health expenditure is still stronger than the remedial impact of renewable energy sources (Çetin, 2019).

These measures, often driven by the direct and indirect costs of environmental degradation on human health, range from improving access to clean water and sanitation services, to investing in renewable energy and reducing CO₂ emissions. However, the effectiveness of these measures varies widely, and further research is needed to understand the specific strategies and policies that are most effective in different contexts.

1.6 Conclusion

In conclusion, the concept of environmental protection has evolved significantly over time, expanding from a focus on preserving natural habitats and wildlife to include efforts to reduce pollution, promote sustainable agriculture, conserve water, and manage waste effectively. This evolution reflects a growing recognition of the intrinsic value of the environment and the need for sustainable land use practices.

The role of renewable energy in environmental protection has become increasingly important, with a focus on reducing greenhouse gas emissions, minimizing waste, and preventing the degradation of land and water resources. The steel industry, a critical sector in the global economy, is under scrutiny due to its significant environmental impact, necessitating a comprehensive approach to address these issues.

Countries across the globe have recognized environmental protection as a pressing issue and have developed a diverse array of strategies, policies, and regulations to address these challenges. These include the adoption of Extended Producer Responsibility (EPR) and the Polluter Pays Principle (PPP), the establishment of comprehensive waste management strategies, and the promotion of renewable energy. However, despite these efforts, significant challenges remain. These include pollution, climate change, water scarcity, biodiversity loss, waste disposal, and energy tensions. Addressing these challenges requires a multifaceted approach that includes policy changes, technological innovations, and individual actions. The interconnectivity of these issues highlights the need for integrated solutions that consider the environmental, social, and economic dimensions of sustainability. In the face of these challenges, the role of governments in environmental protection is indispensable. They are responsible for establishing environmental standards and regulations and ensuring their enforcement. The commitment to environmental protection demonstrated by various countries and regions, including the European Union, the United States, China, India, Japan, and others, provides valuable insights and models for other regions and countries seeking to address environmental challenges.

The urgent need for robust environmental protection measures worldwide is clear. Collective action, policy changes, technological innovations, and individual efforts are all crucial in addressing environmental challenges. Further research is needed to understand the specific strategies and policies that are most effective in different contexts, and to ensure the health and well-being of future generations and the preservation of our natural environment.

Chapter 2: Renewable Energy: A Landscape Analysis and its Industry Implications

The global energy landscape is undergoing a significant transformation, driven by a growing recognition of the unsustainable nature of traditional fossil fuels. The increasing demand for energy, coupled with the finite nature of fossil fuel resources, has led to a situation of energy stress. This is further exacerbated by the environmental implications of fossil fuel consumption, which include air pollution and the emission of greenhouse gases contributing to climate change (Smith et al., 2020).

Renewable energy, often referred to as 'new renewable energy', presents a viable solution to these challenges. Unlike fossil fuels, renewable energy sources are virtually inexhaustible and have a significantly lower environmental impact. These sources include solar, wind, hydro, geothermal, and bioenergy. Each of these types of renewable energy has unique characteristics and potential applications, making them collectively capable of meeting a wide range of energy needs (Johnson & Chertow, 2019). The transition to renewable energy is not merely a matter of technological change. It also requires a comprehensive understanding of the market dynamics and policy frameworks that influence the development and deployment of renewable energy technologies. Market factors, such as cost competitiveness, investment trends, and consumer preferences, play a crucial role in shaping the renewable energy landscape (Brown et al., 2021).

Policy, on the other hand, can serve as a powerful tool to accelerate the shift toward renewable energy. Policies that support renewable energy development range from financial incentives to regulatory measures aimed at leveling the playing field for renewable energy in

comparison to fossil fuels. The effectiveness of these policies can be influenced by a variety of factors, including political will, public opinion, and the state of the economy (Harrison & Thiel, 2018). The transition to renewable energy is a complex process that involves a wide range of factors. Understanding these factors is crucial for developing effective strategies to promote the adoption of renewable energy and mitigate the challenges associated with energy stress and environmental sustainability.

2.1 Photovoltaic

I. Principles

The principle of photovoltaic energy conversion lies in the ability of certain materials to absorb light and convert it into electricity. This process is facilitated by the photovoltaic effect, which is a physical and chemical phenomenon that involves the conversion of light into electrical energy. The photovoltaic effect occurs when photons, or particles of light, knock electrons into a higher state of energy, creating electricity.

Photovoltaic cells, often referred to as solar cells, are devices that generate electricity directly from visible light through this photovoltaic effect. The fundamental principle of operation of a photovoltaic cell is the same as that of the conventional diode. When light shines on the cell, it can be absorbed by the semiconductor material, which can cause electrons to be excited to a state where they can be collected by the electrical circuit, thus generating an electric current. The materials used in photovoltaic cells are semiconductors, materials that have properties between conductors and insulators. The most common semiconductor material used in photovoltaic cells is silicon, although other materials such as gallium arsenide, copper indium gallium selenide, and cadmium telluride are also used. These materials are chosen for their ability to absorb light and their electrical properties.

In terms of efficiency, photovoltaic cells can convert light into electricity with varying degrees of efficiency. The efficiency of a photovoltaic cell is defined as the ratio of the electrical power output to the incident light power. The efficiency of photovoltaic cells can be affected by several factors, including the quality of the semiconductor material, the amount and type of light that the cell is exposed to, and the temperature of the cell. Compared to traditional fossil fuels, photovoltaic energy has several advantages. It is a renewable source of energy, meaning it is not depleted when used. It also does not produce harmful emissions or contribute to climate change. However, the efficiency of photovoltaic cells is generally lower than that of traditional fossil fuel energy sources, and the initial cost of installing photovoltaic systems can be high.

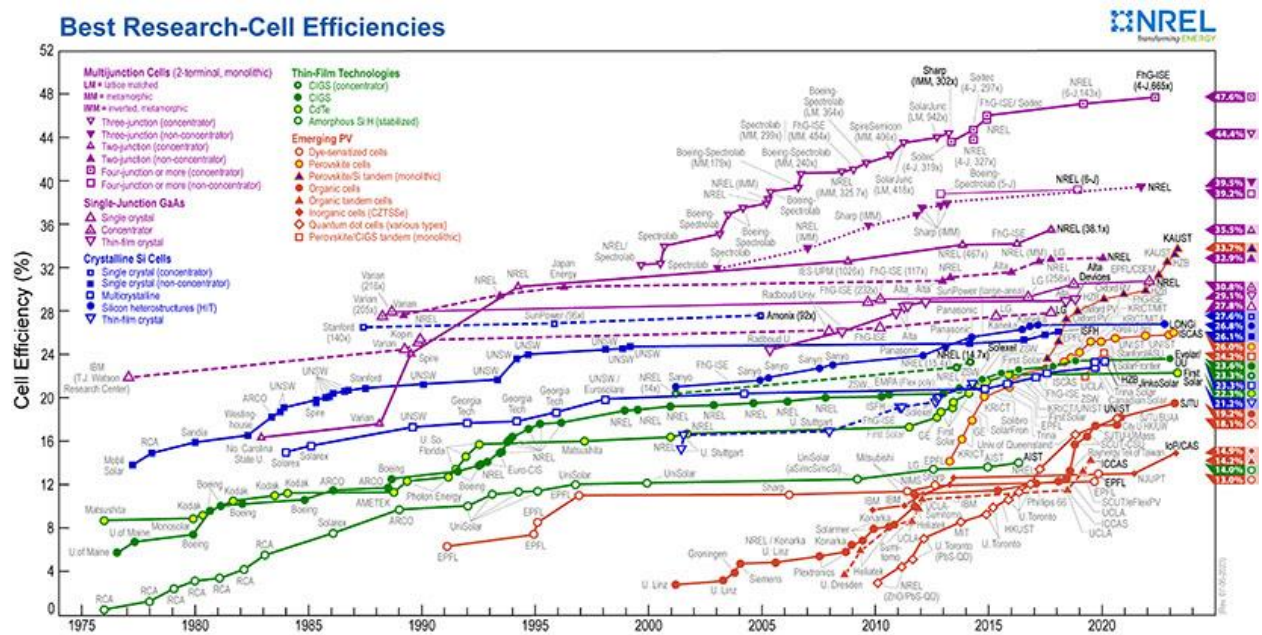


Figure 2 NREL data chart for photovoltaic efficiencies changes over the worldwide.

II. Crystalline Silicon Photovoltaic Cells

Crystalline silicon photovoltaic cells are the most widely used type of solar cells in the industry, accounting for about 90% of the global photovoltaic market (Green et al., 2018). These

cells are made from silicon, a semiconductor material that is abundant and non-toxic. The high efficiency and long-term stability of crystalline silicon cells make them a popular choice for solar energy generation.

The fabrication process of crystalline silicon cells involves several steps. First, high-purity silicon is produced from raw silicon by a refining process. The purified silicon is then melted and cooled to form a single crystal silicon ingot. This ingot is cut into thin wafers, which are then doped with impurities to create a p-n junction, a critical component in photovoltaic cells. The wafers are coated with an anti-reflective layer to increase light absorption and metal contacts are added to collect the electric current. The finished cells are then assembled into solar panels (Green et al., 2018). The efficiency of crystalline silicon cells is one of their key advantages. As of 2018, the record efficiency for a laboratory cell was 26.6%, while commercial modules typically have efficiencies between 15% and 20% (Green et al., 2018). This high efficiency, combined with their long-term stability and reliability, makes crystalline silicon cells a cost-effective choice for solar energy generation.

Compared to traditional fossil fuels, solar energy generated from crystalline silicon cells has several advantages. Solar energy is renewable, abundant, and emits no greenhouse gases during operation. In contrast, the extraction and combustion of fossil fuels are associated with environmental degradation and the emission of greenhouse gases, which contribute to climate change. Furthermore, unlike fossil fuels, the "fuel" for solar cells—sunlight—is free and available in all parts of the world. However, it's important to note that while the operation of solar cells does not produce greenhouse gas emissions, the production of the cells themselves does have an environmental impact. The purification of silicon and the manufacturing of cells require significant energy, much of which is currently provided by fossil fuels. This results in the

emission of greenhouse gases during the production of solar cells. However, as the energy sector shifts towards renewable sources, the carbon footprint of solar cell production can be expected to decrease (Fthenakis et al., 2008).

In terms of environmental treatments, solar energy has several positive impacts. It does not produce air or water pollution during operation, and it does not require water for cooling, unlike many conventional power plants. Solar energy can also have positive impacts on pollinators. For example, solar farms can be combined with pollinator habitats, providing a dual benefit of renewable energy generation and biodiversity conservation (Barron-Gafford et al., 2019). However, like any industrial activity, the production of solar cells does have some environmental impacts. These include the use of hazardous materials in the manufacturing process, the generation of waste, and the potential for land use impacts from large-scale solar farms. These impacts need to be managed through appropriate environmental regulations and industry best practices.

In conclusion, crystalline silicon photovoltaic cells are a mature and efficient technology for solar energy generation. They offer a renewable and widely available energy source with significant environmental benefits compared to fossil fuels. However, the environmental impacts of cell production need to be managed to ensure the sustainability of this technology.

III. Perovskite

Perovskite solar cells have emerged as a promising alternative to traditional silicon-based photovoltaics due to their high efficiency and low production costs. The term 'perovskite' refers to a unique crystal structure that is formed by a variety of different materials. The most

commonly used material in perovskite solar cells is methylammonium lead iodide ($\text{CH}_3\text{NH}_3\text{PbI}_3$) (Espinosa et al., 2012).

The fabrication process of perovskite solar cells is relatively straightforward and cost-effective. The perovskite layer is typically deposited onto a substrate using a solution-based process, which allows for the production of thin, lightweight, and flexible solar cells. This process also enables the production of perovskite solar cells on a large scale, making them a viable option for commercialization (Espinosa et al., 2012). In terms of efficiency, perovskite solar cells have shown remarkable progress. Since their inception, the efficiency of perovskite solar cells has increased from 3.8% in 2009 to over 25% in recent years, rivaling that of traditional silicon-based solar cells. This rapid improvement in efficiency is largely due to the unique properties of perovskite materials, including their high absorption coefficient, long carrier diffusion length, and tunable bandgap (Espinosa et al., 2012).

When compared to traditional fossil fuels, perovskite solar cells offer several advantages. They produce energy without emitting greenhouse gases, making them a clean and sustainable energy source. Additionally, the energy payback period (EPBP) of perovskite solar cells is relatively short compared to other photovoltaic technologies. The EPBP is the time it takes for a solar cell to generate the amount of energy that was used to produce it. For perovskite solar cells, the EPBP is shorter than that of silicon and CdTe based PV cells, due to their efficient fabrication routes based on roll-to-roll (R2R) processing (Gong et al., 2015). However, it's worth noting that the lifespan of perovskite solar cells is currently a topic of ongoing research. While the lifespan of other existing PV technologies is well-established, assumptions have been made about the lifespan of perovskite solar cells. As the technology matures, it is expected that the lifespan of

perovskite solar cells will increase significantly, thereby improving their overall performance and cost-effectiveness (Gong et al., 2015).

In conclusion, perovskite solar cells represent a promising technology in the field of renewable energy. Their high efficiency, low production costs, and potential for large-scale production make them a viable alternative to traditional silicon-based photovoltaics and fossil fuels. However, further research is needed to improve their lifespan and stability, which are crucial factors for their commercialization and widespread adoption.

IV. Thin Film

Thin film photovoltaic (PV) cells are a type of solar cell that feature a thin semiconductor active layer for light absorption and charge carrier transport. The thin film technology offers several advantages over traditional silicon-based PV cells, including lower material costs, lighter weight, and greater flexibility, which makes them suitable for a variety of applications such as building-integrated photovoltaics (BIPV) and portable power generation. There are several types of thin film PV technologies, each using a different semiconductor material:

Amorphous Silicon (a-Si): This is the most mature thin film technology, having been developed in the 1970s. The semiconductor layer in a-Si cells is non-crystalline, which leads to a lower efficiency compared to crystalline silicon. However, a-Si cells perform better in low-light conditions and are more resistant to heat.

Cadmium Telluride (CdTe): CdTe cells offer the highest efficiency among thin film technologies and are also the most cost-effective to manufacture. However, the use of cadmium, a toxic heavy metal, raises environmental concerns.

Copper Indium Gallium Selenide (CIGS): CIGS cells have shown the highest efficiency among thin film cells in laboratory conditions. They use a complex four-element alloy, which makes the manufacturing process more challenging and expensive.

Perovskite Cells: These are a newer type of thin film cell that have shown rapid increases in efficiency in the lab. They use a perovskite structured compound, most commonly a hybrid organic-inorganic lead or tin halide-based material, as the light-harvesting active layer.

The fabrication process of thin film cells typically involves depositing several layers of materials, including the semiconductor layer, onto a substrate. This can be done using various techniques such as physical vapor deposition (PVD), chemical vapor deposition (CVD), electroplating, or printing. In terms of efficiency, thin film cells generally lag behind crystalline silicon cells. However, the gap has been narrowing, especially with the development of perovskite and CIGS cells. When compared to traditional fossil fuels, thin film cells, like all solar cells, produce energy without emitting greenhouse gases, making them a clean and sustainable energy source.

However, it's worth noting that the lifespan and degradation rates of thin film cells, especially newer technologies like perovskite, are topics of ongoing research. As these technologies mature, it is expected that their lifespan and stability will improve, thereby enhancing their overall performance and cost-effectiveness.

V. Potential Environmental Impacts

Photovoltaic technologies, including silicon, perovskite, and thin-film cells, have been widely adopted due to their ability to convert sunlight into electricity. However, their environmental impacts are a topic of ongoing research and discussion.

Silicon-based photovoltaic cells, particularly crystalline silicon (c-Si), are the most widely used in the industry. However, the production process of c-Si cells involves high energy consumption and the emission of harmful substances. The production of silicon wafers requires high temperatures, leading to significant energy consumption and CO₂ emissions (Fthenakis et al., 2008). Moreover, the production process involves the use of hazardous chemicals, such as hydrochloric acid, sulfuric acid, and sodium hydroxide, which can cause environmental pollution if not properly managed (Fthenakis et al., 2008).

Perovskite photovoltaic cells have attracted attention due to their high efficiency and low production cost. However, the environmental impact of perovskite cells is a concern due to the use of lead, a toxic material, in their production. The leakage of lead from perovskite cells into the environment can cause serious health and environmental problems (Hailegnaw et al., 2019). Furthermore, the stability of perovskite cells is lower than that of silicon cells, which may lead to more frequent replacement and disposal, potentially causing additional environmental impact (Hailegnaw et al., 2019).

Thin-film photovoltaic cells, including CdTe, CIGS, and a-Si cells, have lower efficiency than silicon and perovskite cells, but they are cheaper and easier to produce. However, the environmental impact of thin-film cells is also significant. The production of CdTe cells involves the use of cadmium, a toxic material, which can cause environmental pollution if not properly

managed (Fthenakis, 2004). The production of CIGS cells involves the use of indium, a scarce material, leading to concerns about resource depletion (Fthenakis, 2004).

The recycling of waste solar panels is an essential aspect of the photovoltaic industry, as it addresses the environmental concerns associated with the disposal of these materials. The recycling process involves several steps, including thermal treatment to remove Ethylene Vinyl Acetate (EVA) and chemical treatment to separate metals and recover silicon from the panels (Castro-Montalvo et al., 2021). The thermal treatment involves heating the panels at 650°C for 30 minutes, which ensures minimum energy expenditure and complete combustion of samples (Castro-Montalvo et al., 2021). Following this, the panels undergo a chemical etching process to recover silicon and separate metals. The etching solution used in this process typically consists of 5 mL of nitric acid (HNO₃, 70%) and 0.5 mL of hydrofluoric acid (HF, 40%), in a 10:1 proportion (Castro-Montalvo et al., 2021). The efficiency of the silicon recovery process depends on the composition of the photovoltaic technology. For instance, the etching process parameters must be controlled, such as the composition and concentration of the acid solution, the temperature, and the time to which the samples are subjected to the process (Castro-Montalvo et al., 2021). The use of high temperatures requires energy expenditure, and an excess of reagents increases the possibility of environmental contamination and cost; so, it is desirable to minimize these parameters (Castro-Montalvo et al., 2021). The recovered product after removing EVA contains materials used for the antireflective coating, the p-n junction, and the contact electrodes, in addition to silicon (Castro-Montalvo et al., 2021). The hydrofluoric acid promotes complete etching of the metals, due to its high aggressivity and possibility to dissolve almost all inorganic materials, except silver. It dissolves the oxidation layers that could form because of the action of nitric acid on metals (Castro-Montalvo et al., 2021). The metals of interest in this work (Cu, Ag,

Pb) were obtained after the chemical treatment in the form of ions (Cu^{2+} , Pb^{2+} , Ag^{+}) in the solution. The quantification of these metals was also done as a function of etching time, using the Atomic Absorption Spectroscopy technique (Castro-Montalvo et al., 2021). The recycling process is not without its challenges. For instance, the size of the recovered silicon particles is not homogeneous, and in some cases, they are still attached to glass fractions (Castro-Montalvo et al., 2021). However, the process is essential for the sustainable use of photovoltaic technology and the mitigation of environmental impacts associated with waste solar panels.

In conclusion, while photovoltaic technologies provide a promising solution to the energy crisis, their environmental impacts cannot be ignored. Future research should focus on improving the production process of photovoltaic cells to reduce their environmental impact, as well as developing recycling technologies to manage photovoltaic waste.

2.2 Wind

I. Wind Energy: An In-depth Examination

Wind energy, a key player in the renewable energy sector, harnesses the kinetic energy of the wind to generate electricity. This form of energy conversion is facilitated by wind turbines, which are complex structures designed to capture and convert wind's kinetic energy into mechanical energy, which is then transformed into electrical energy (Manwell, McGowan, & Rogers, 2009).

The primary component of a wind turbine is the rotor, which includes the blades and the hub. The materials used in the construction of wind turbines vary, but the most common materials are fiberglass, resin, and balsa wood for the blades, and steel for the tower. These materials are chosen for their strength, durability, and resistance to weather conditions (Manwell et al., 2009).

II. Fabrication Process

The fabrication process of wind turbines is a complex, multi-stage operation that requires precision and expertise. The primary components of a wind turbine are the rotor, which includes the blades and the hub, the tower, and the nacelle, which houses the generator and gearbox (Manwell, McGowan, & Rogers, 2009).

The blades of a wind turbine are typically made from composite materials such as fiberglass, resin, and balsa wood. The fabrication of the blades begins with the creation of a mold, which is then filled with the composite materials. The materials are layered and bonded together under heat and pressure to form a strong, lightweight blade. The blades are then coated with a

protective layer to withstand the harsh weather conditions they will be exposed to (Manwell et al., 2009). The tower of a wind turbine is typically made from steel. The fabrication process involves cutting and shaping the steel into sections, which are then welded together to form the tower. The tower is designed to be strong enough to support the weight of the rotor and the nacelle, and tall enough to allow the blades to capture the wind's energy effectively. The tower is then coated with a protective layer to prevent corrosion (Manwell et al., 2009). The nacelle houses the generator and gearbox, which are critical components in the energy conversion process. The generator is made from copper and steel, and the gearbox is made from steel. The fabrication process involves machining the components to precise specifications, assembling them, and testing them to ensure they function correctly. The nacelle is then assembled, with the generator and gearbox installed inside (Manwell et al., 2009).

Once the blades, tower, and nacelle have been fabricated, they are transported to the installation site. The installation process involves erecting the tower, attaching the nacelle to the top of the tower, and attaching the blades to the hub of the rotor. The turbine is then connected to the electrical grid, and final checks are carried out to ensure it is operating correctly (Manwell et al., 2009). The fabrication and installation of wind turbines require a significant investment of time and resources. However, the declining costs of wind energy, coupled with its environmental benefits, make it a viable and sustainable alternative to traditional fossil fuels.

The cost of wind energy has been decreasing over the years, making it a competitive alternative to traditional fossil fuels. Technological advancements, economies of scale, and improved efficiency have contributed to this cost reduction. As of 2020, the levelized cost of electricity (LCOE) from onshore wind fell to a range of 3-6 cents per kilowatt-hour, compared to 5-17 cents per kilowatt-hour for most new fossil fuel power plants (IRENA, 2020).

In terms of efficiency, wind turbines convert around 45% of the wind's kinetic energy into electrical energy under optimal conditions. This is a significant achievement, considering that traditional fossil fuel power plants have efficiencies ranging from 33% to 50%. The efficiency of wind turbines is dependent on several factors, including wind speed, air density, and turbine design (EIA, 2020).

III. Environmental Treatments: Advantages, Disadvantages, and Installation Challenges

Wind energy offers significant environmental benefits. It produces electricity without emitting greenhouse gases or air pollutants, contributing to a reduction in carbon footprint. This is a significant advantage over fossil fuels, which are major contributors to global warming and air pollution (Saidur, Rahim, Islam, & Solangi, 2011). However, there are also environmental challenges associated with wind energy. Wind turbines can have negative impacts on wildlife, particularly birds and bats. The rotating blades can cause fatalities, and the presence of the turbines can disrupt migration patterns and habitats (Drewitt & Langston, 2006). Furthermore, the noise and visual impact of wind turbines can cause issues for local communities, leading to opposition to wind farm projects.

Installation of wind turbines can present challenges. These systems require a significant amount of space, which can be a constraint in densely populated areas. The installation process is complex and requires skilled labor, which can increase the cost. The site selection process also needs to consider wind speed and direction, proximity to electrical grids, and environmental and social impacts (Manwell et al., 2009).

In terms of noise, wind turbines do produce sound during operation. However, modern turbine design has significantly reduced the noise levels. The sound is often described as a whooshing noise, and while it can be heard up close, at a distance of about 300 meters, the noise is usually masked by background noise. Furthermore, wind turbines are often installed in remote locations where the noise impact is minimal (Pedersen & Waye, 2004).

2.3 1. Nuclear Fusion and Fission Energy

Nuclear energy, a potent source of power, is derived from the processes of nuclear fusion and fission. Nuclear fission involves the splitting of large atomic nuclei, typically uranium-235 or plutonium-239, into smaller ones, releasing a large amount of energy in the process. On the other hand, nuclear fusion involves the combining of small atomic nuclei, usually hydrogen isotopes, into larger ones, also releasing a significant amount of energy (Krane, 1987). The materials used in nuclear reactors vary depending on the type of reactor and the process involved. For fission reactors, enriched uranium or plutonium is used as fuel. For fusion reactors, which are still in the experimental stage, hydrogen isotopes such as deuterium and tritium are used (Krane, 1987). The fabrication process for nuclear reactors is complex and requires stringent safety measures. For fission reactors, the fuel is fabricated into ceramic pellets, which are then loaded into fuel rods. For fusion reactors, the fuel is typically in the form of a plasma confined in a magnetic field (Krane, 1987). The cost of nuclear energy is higher than that of traditional fossil fuels due to the high capital costs of building and maintaining nuclear power plants. However, once a plant is operational, the cost of generating electricity is relatively low due to the high energy density of nuclear fuel (World Nuclear Association, 2020).

In terms of efficiency, nuclear power plants convert about 33-37% of the energy in nuclear fuel into electrical energy, which is comparable to the efficiency of fossil fuel power plants (EIA, 2020).

I. Fusion Energy

Nuclear fusion, the process that fuels the sun and stars, involves the merging of light atomic nuclei into heavier ones, releasing a tremendous amount of energy. The fusion reaction that holds the most promise for power generation combines the hydrogen isotopes deuterium and tritium to form helium and a neutron, converting a small amount of mass into a large amount of energy (Krane, 1987). The fuel for fusion reactors, deuterium and tritium, is abundant and widely available. Deuterium can be extracted from seawater, and tritium can be produced from lithium, which is also abundant. This abundance and availability make fusion a potentially sustainable energy source (Krane, 1987).

The fabrication process for fusion reactors is complex and currently in the experimental stage. The fuel, typically in the form of plasma, is confined within a magnetic field. The most common design for a fusion reactor is the tokamak, a toroidal or doughnut-shaped device that uses magnetic fields to confine and control the plasma (World Nuclear Association, 2020). The tokamak, first developed in the 1950s by Soviet physicists, is designed to contain the high-temperature plasma (in the millions of degrees) necessary for fusion reactions. The magnetic field in the tokamak is created by a combination of external coils and an electric current driven through the plasma. This magnetic field confines the plasma and keeps it away from the reactor walls, which would melt at the temperatures required for fusion. The shape of the tokamak is

critical for maintaining the stability of the plasma and maximizing the efficiency of the confinement (World Nuclear Association, 2020).

The cost of fusion energy is challenging to estimate as it is still in the research and development stage. However, the high capital costs of building and maintaining fusion reactors, as well as the technical challenges associated with achieving and sustaining a controlled fusion reaction, suggest that the cost will be high (World Nuclear Association, 2020). A fusion reaction releases about four times more energy per unit of mass than a fission reaction. However, the challenge lies in achieving and maintaining the conditions necessary for a fusion reaction to occur. This requires a significant amount of energy, and so far, no experimental fusion reactor has been able to produce more energy than it consumes (World Nuclear Association, 2020).

II. Fission Energy

Nuclear fission is a process that involves the splitting of large atomic nuclei, typically uranium-235 or plutonium-239, into smaller ones, releasing a large amount of energy. This energy release is harnessed in nuclear power plants to generate electricity (Krane, 1987).

The fuel used in fission reactors is typically uranium or plutonium. Uranium-235, the most commonly used fuel, is a naturally occurring isotope of uranium, but it only makes up about 0.7% of natural uranium. Therefore, the uranium is usually enriched to increase the concentration of uranium-235 before it can be used as fuel. Plutonium-239, another potential fuel, is produced in the reactor from uranium-238 (Krane, 1987). The fabrication process for fission reactors involves several steps. The uranium or plutonium fuel is formed into ceramic pellets, which are then loaded into long, thin tubes to create fuel rods. These fuel rods are then grouped together to

form a fuel assembly, which is inserted into the reactor core. The reactor core is where the fission reactions take place (Krane, 1987).

The cost of nuclear fission energy is relatively high due to the high capital costs of building and maintaining nuclear power plants. However, once a plant is operational, the cost of generating electricity is relatively low due to the high energy density of nuclear fuel. This makes the levelized cost of electricity (LCOE) from nuclear power competitive with other forms of electricity generation (World Nuclear Association, 2020). In terms of efficiency, nuclear power plants convert about 33-37% of the energy in nuclear fuel into electrical energy. This is comparable to the efficiency of fossil fuel power plants. The efficiency of a nuclear power plant is limited by the need to prevent the reactor core from overheating, which could lead to a meltdown (EIA, 2020).

III. Environmental Treatments: Advantages, Disadvantages, and Installation Challenges

Nuclear energy, both fusion and fission, presents a unique set of environmental advantages and challenges. On the positive side, nuclear power plants produce electricity without emitting greenhouse gases or air pollutants, making them an attractive option for mitigating climate change. The high energy density of nuclear fuel also means that nuclear power plants require less land than most renewable energy sources for the same amount of power generation (Bodansky, 2004). However, the production of nuclear energy also generates radioactive waste, which requires careful management and disposal. This waste can remain radioactive for thousands of years, posing a long-term environmental and health risk. The disposal of nuclear waste is a complex and contentious issue, with deep geological repositories being the most widely accepted solution (Bodansky, 2004).

The recent issue with Japan's Fukushima nuclear plant highlights the challenges associated with managing nuclear waste. After the 2011 earthquake and tsunami, the plant's reactors were damaged, and large amounts of cooling water became contaminated with radioactive materials. This water has been stored on-site, but storage capacity is running out. The Japanese government has decided to treat the water to remove most of the radioactive materials and then gradually release it into the ocean, a decision that has sparked international controversy due to concerns about the potential environmental impact (BBC, 2021). Nuclear power plants also present safety concerns. While the operation of a nuclear power plant does not emit pollutants into the atmosphere, accidents at nuclear power plants can have severe environmental and health impacts, as evidenced by the Chernobyl and Fukushima disasters (Hasegawa et al., 2015). The installation of nuclear power plants presents significant challenges. These facilities require a large amount of space and must be located away from densely populated areas due to safety concerns. The construction process is complex and requires a high level of expertise, and the regulatory approval process can be lengthy and costly (World Nuclear Association, 2020).

IV. Multiple Renewable Energy Hybrid

Hybrid energy systems, which combine different forms of renewable energy, are emerging as a promising solution for achieving a sustainable and resilient energy future (Khan et al., 2021). Hybrid renewable energy systems can include various combinations of energy sources, such as wind, solar, and hydro power. These systems can be designed to optimize energy production based on the availability and variability of different energy sources. For example, a hybrid system might use solar power during the day when sunlight is abundant and switch to wind power at night when wind speeds are typically higher (Liu et al., 2020). The integration of

multiple renewable energy sources into a single system can enhance the reliability and stability of the power supply. However, managing the complex interactions between different energy sources and balancing supply and demand in real-time can be challenging. This is where the concept of the "industrial internet" comes into play (Puri et al., 2019).

The industrial internet, also known as the Industrial Internet of Things (IIoT), involves the use of sensors, software, and communication technologies to collect, analyze, and exchange data in real-time. In the context of hybrid renewable energy systems, the industrial internet can be used to monitor the performance of different energy sources, predict energy production based on weather forecasts, and control the distribution of power to different usage branches (Puri et al., 2019). For example, an IIoT-based system can generate electrical energy from multiple sensors for household appliances and industrial areas. Different sensors, namely piezoelectric sensor, body heat to electric converter, and solar panel, are utilized and connected to the power storage circuit for generation of electrical energy. Artificial Intelligence (AI) models such as Artificial Neural Network (ANN), Adaptive Network based Fuzzy Inference System (ANFIS) are utilized for the total power generated from renewable energy resources (Puri et al., 2019).

IIoT is a key element in the fourth industrial revolution or Industry 4.0, which is characterized by the fusion of the digital, physical, and biological worlds (Lee, Bagheri, & Kao, 2015). In the context of multiple renewable energy hybrid systems, the industrial internet plays a crucial role in managing and optimizing the operation of these complex systems. It involves the use of sensors, software, and communication technologies to collect, analyze, and exchange data in real-time. This real-time data collection and analysis enable the system to respond promptly to changes in energy demand or supply, thereby enhancing the reliability and efficiency of the power supply (Puri et al., 2019).

For instance, sensors can monitor the performance of different energy sources, such as the output of a solar panel or the wind speed at a wind turbine. This data can then be analyzed to predict energy production based on weather forecasts or to identify potential issues that may affect the performance of the system. Moreover, the industrial internet can control the distribution of power to different usage branches, ensuring that the power supply meets the demand in the most efficient way possible (Puri et al., 2019). The industrial internet also facilitates the integration of renewable energy into the grid. It can manage the variable and intermittent nature of renewable energy, balancing the supply and demand of power, and ensuring grid stability. Furthermore, it can enable smart grid functionalities, such as demand response, where the power consumption of end-users can be adjusted based on the availability of renewable energy (Lee, Bagheri, & Kao, 2015).

However, the implementation of the industrial internet in multiple renewable energy hybrid systems also presents challenges, including data security and privacy issues, the need for standardization, and the requirement for advanced data analytics capabilities. Addressing these challenges will be crucial for realizing the full potential of the industrial internet in the renewable energy sector. Multiple renewable energy hybrid systems, combined with the industrial internet, offer a promising pathway towards a sustainable and resilient energy future. However, further research and development are needed to overcome the technical challenges associated with integrating multiple energy sources and managing complex energy systems.

4. Chapter 3: Fossil Fuels Versus Renewable Energy: Assessing Environmental Impacts and Sustainability

I. Fossil Fuels

Fossil fuels, comprising primarily of coal, oil, and natural gas, have been the backbone of the global energy system for many centuries. They powered the industrial revolution, fuelled economic growth, and continue to meet the majority of the world's energy needs. However, the extraction, processing, and consumption of fossil fuels have significant environmental implications, which are becoming increasingly unsustainable (Borysenko et al., 2023). The burning of fossil fuels for electricity, heat, and transportation is the largest single source of global greenhouse gas emissions. These emissions primarily consist of carbon dioxide (CO₂), a major contributor to global warming and subsequent climate change. The combustion process releases this gas into the atmosphere, where it traps heat and raises the planet's average temperature. This process has led to a range of climate-related impacts, including rising sea levels, changing weather patterns, and increased frequency and intensity of extreme weather events (Payandeh et al., 2021). In addition to CO₂, the extraction and production processes of fossil fuels release methane, a greenhouse gas that is significantly more potent than CO₂ in terms of its heat-trapping capacity. Methane leaks from oil and gas wells, pipelines, and other infrastructure represent a major source of greenhouse gas emissions that are often overlooked in discussions about climate change (Payandeh et al., 2021).

Beyond greenhouse gas emissions, the use of fossil fuels leads to the production of a wide array of petrochemical by-products. The petrochemical industry, which relies heavily on fossil fuels as feedstock, produces a vast range of products, including plastics, fertilizers, and

synthetic fibers. However, these processes and the subsequent disposal of these products can lead to severe environmental problems. For instance, plastic waste has emerged as a significant global issue, contributing to ocean pollution and posing a threat to marine life. Furthermore, many petrochemical processes release harmful pollutants into the air, water, and soil, which can have detrimental effects on human health and the broader environment (Borysenko et al., 2023). The extraction of fossil fuels also has direct environmental impacts. These include habitat destruction, water pollution, and soil erosion. For instance, oil spills, which are a risk associated with oil extraction and transportation, can have devastating effects on marine and coastal ecosystems. Coal mining, particularly methods such as mountaintop removal and strip mining, can lead to significant landscape alteration, loss of biodiversity, and contamination of water sources (Smyth et al., 2020).

In contrast, renewable energy sources such as wind, solar, and hydro power offer the potential for sustainable energy production with significantly reduced environmental impacts. However, transitioning to a renewable energy future will require overcoming numerous technical, economic, and social challenges. The following sections will explore these renewable energy sources and their potential to replace fossil fuels in more detail.

II. Renewable Energy

While renewable energy systems do not emit greenhouse gases during operation, their production and installation processes can have environmental impacts. For instance, the manufacturing of solar panels and wind turbines requires the extraction and processing of raw materials, which can lead to habitat destruction, water pollution, and greenhouse gas emissions. Moreover, the disposal of waste equipment from renewable energy production, such as used

solar panels and wind turbine blades, presents a significant waste management challenge (Osman et al., 2022).

Despite these challenges, advancements in technology and circular economy practices offer promising solutions. For example, the use of recycled building materials in the construction of renewable energy systems can significantly reduce their environmental impact. Moreover, the recycling and reuse of waste equipment from renewable energy production can help to mitigate the waste management challenge. However, these practices are not yet widespread, and further research and development are needed to make them more feasible and cost-effective (Papadaki, Nikolaou, & Assimakopoulos, 2022). Furthermore, the environmental impact of renewable energy systems can vary depending on the specific technology and location. For instance, hydropower projects can have significant environmental impacts, including habitat destruction and alteration of water flows, particularly for large-scale projects. On the other hand, solar and wind energy systems generally have lower environmental impacts, especially when sited appropriately to minimize impacts on wildlife and ecosystems (Osman et al., 2022).

The rapid expansion of solar energy applications has led to a significant increase in solar panel waste, which poses both recycling challenges and environmental hazards. The manufacturing of solar panels involves the use of various materials, including metals, glass, and plastic. When these panels reach the end of their lifespan, typically around 25-30 years, they become a source of waste. The International Renewable Energy Agency (IRENA) estimates that by 2050, the world could have up to 78 million metric tons of solar panel waste (Osman et al., 2022). The disposal of solar panel waste is a complex issue. Landfilling, the most common disposal method, can lead to the leaching of hazardous materials, such as lead and cadmium, into the environment. These materials can contaminate soil and water resources, posing risks to

ecosystems and human health. Moreover, valuable materials, such as silver and silicon, are lost when solar panels are landfilled, representing a significant economic waste (Sharma, Mahajan, & Garg, 2023). The recycling of solar panels is a potential solution to this problem. However, current recycling processes are often energy-intensive and can also lead to environmental pollution. For instance, the process of recovering silicon from solar panels involves the use of strong acids, which can generate hazardous waste. Moreover, the recycling rates for solar panels are currently low, due in part to the lack of effective recycling infrastructure and regulations in many countries (Hua & Imam, 2022). A novel recycling concept employing high-temperature density separation has been proposed to address these challenges. This method offers many benefits, such as higher efficiency, potential for energy recovery, and lower environmental impact. It also has the potential to make recycling a profitable practice, thereby incentivizing the recycling of solar panels. However, further research and development are needed to make this method more feasible and cost-effective (Hua & Imam, 2022).

The environmental impacts of renewable energy sources extend beyond their operation phase. For instance, the production of nuclear energy, while producing zero greenhouse gas emissions during operation, results in nuclear waste, which poses significant environmental and health risks. Nuclear waste, particularly high-level waste, remains radioactive for thousands of years and requires careful management and disposal to prevent contamination of the environment and harm to human health. Moreover, nuclear power plants, like all large-scale industrial facilities, have the potential to impact local ecosystems during their construction and operation (Osman et al., 2022).

The impact of wind energy on pollinators is another area of concern. Wind turbines can pose a threat to flying insects, including pollinators such as bees and butterflies. The blades of

wind turbines can cause direct mortality to insects, while the noise and vibration produced by wind turbines may disrupt insect behavior and potentially affect pollination processes. However, the extent of these impacts is still not fully understood, and further research is needed to assess the potential effects of wind energy on pollinators and to develop strategies to mitigate these impacts (Thess & Lengsfeld, 2022).

In conclusion, while renewable energy systems have environmental impacts, they are generally lower than those of fossil fuels, particularly in terms of greenhouse gas emissions. Moreover, with advancements in technology and circular economy practices, the environmental impacts of renewable energy systems can be further reduced.

5. Chapter 4: Green Finance in the Context of Renewable Energy and Environmental Protection: A Critical Review

Green finance has emerged as a critical tool in the transition towards a more sustainable and low-carbon economy. It encompasses financial investments flowing into sustainable development projects and initiatives, environmental products, and policies that encourage the development of a more sustainable economy (Topić-Pavković, 2020).

In the context of renewable energy, green finance plays a pivotal role. The development and deployment of renewable energy technologies require substantial investments. Green finance mechanisms, such as green bonds, green loans, and green funds, provide the necessary capital for these investments. These financial instruments are designed to support projects that have environmental benefits, such as renewable energy projects, energy efficiency initiatives, and other projects that contribute to the mitigation of climate change (Ye et al., 2022). However, the role of green finance is not limited to providing financial resources. It also involves managing risks associated with green investments and ensuring that the financial system is aligned with the goals of environmental sustainability and climate resilience. This includes assessing the environmental risks and impacts of investments, promoting transparency in green investments, and encouraging the adoption of sustainable business practices (Gao et al., 2023).

Green finance also plays a crucial role in environmental protection. It provides the funding needed for projects aimed at preserving biodiversity, reducing pollution, managing natural resources sustainably, and adapting to climate change. Moreover, green finance can incentivize businesses and individuals to adopt more environmentally friendly practices. For instance, green loans or grants can be used to encourage businesses to reduce their environmental

footprint, while green mortgages can incentivize homeowners to invest in energy-efficient homes (Liu & Xia, 2022). However, the effectiveness of green finance in promoting environmental protection depends on various factors, including the regulatory framework, the availability of green financial products, the level of awareness and understanding of green finance among investors and consumers, and the capacity to monitor and verify the environmental impact of green investments (Ye et al., 2022).

Green finance is a critical enabler of renewable energy and environmental protection. However, to fully harness its potential, there is a need for supportive policy frameworks, increased transparency, and improved capacity for environmental risk assessment and impact verification.

I. Carbon Credit and Carbon Trade

Carbon credits are a type of financial instrument aimed at reducing greenhouse gas emissions. They provide a way to offset emissions by financing projects that reduce, avoid, or remove greenhouse gas emissions from the atmosphere. These projects can range from renewable energy projects to forest conservation initiatives. By purchasing carbon credits, businesses and individuals can offset their own carbon emissions and contribute to the global effort to mitigate climate change. Moreover, the carbon credit market can incentivize the development of green technologies and practices by providing a financial reward for reducing emissions (Xing, Li, & Yu, 2022).

The effectiveness of carbon credits and carbon trade in promoting emission reductions is influenced by various factors. One of the key factors is the stringency of the cap on emissions.

The cap sets the total amount of emissions that are allowed under the trading system. If the cap is set too high, it may not provide sufficient incentive for entities to reduce their emissions.

Conversely, if the cap is set too low, it may impose excessive costs on entities and potentially harm economic growth (Zhang, Wang, & Wang, 2022). The allocation of allowances is another important factor. Allowances are the permits that entities need to emit greenhouse gases under a cap-and-trade system. The method of allocating these allowances can influence the distribution of costs and benefits under the trading system. For instance, if allowances are given away for free, it may benefit entities that have high emissions and discourage them from reducing their emissions. On the other hand, if allowances are auctioned, it can generate revenue that can be used to fund emission reduction projects or to compensate disadvantaged communities that are disproportionately affected by pollution (Lejano, Kan, & Chau, 2020).

The monitoring and verification of emissions are crucial for the integrity of the carbon trading system. Accurate and reliable measurement of emissions is necessary to ensure that entities are complying with their emission limits and that the emission reductions achieved through the trading system are real and verifiable. Moreover, robust monitoring and verification can enhance transparency and trust in the trading system (Zhang, Wang, & Wang, 2022). The governance of the trading system is also a critical factor. The rules and regulations of the trading system, the enforcement of these rules, and the resolution of disputes are all aspects of governance that can influence the effectiveness of the trading system. Good governance can ensure that the trading system operates fairly and efficiently and that it delivers the intended environmental benefits (Chaban, Dudt, Gordon, & Ostrowski, 2021).

Moreover, it is important to ensure that the carbon trading system promotes environmental justice. This means that the system should not disproportionately burden

disadvantaged communities with the costs of pollution or the impacts of climate change. For instance, carbon trading can lead to the creation of "toxic hotspots" where pollution is concentrated, often in communities that are already overburdened by pollution. Therefore, the design of the carbon trading system should take into account its potential impacts on environmental justice (Lejano, Kan, & Chau, 2020).

II. ESG (Environment, Social, Government)

On the other hand, ESG criteria are used by investors to assess a company's performance on environmental, social, and governance issues. Environmental criteria consider how a company performs as a steward of the natural environment. Social criteria examine how a company manages relationships with its employees, suppliers, customers, and the communities where it operates. Governance deals with a company's leadership, executive pay, audits, internal controls, and shareholder rights. ESG investing is based on the premise that companies that perform well on these issues are more likely to be financially successful in the long term. By incorporating ESG criteria into their investment decisions, investors can support companies that are committed to sustainability and responsible business practices (Feng, Shang, An, & Yang, 2022).

However, ESG reporting can be problematic due to issues with reporting quality. Traditional financial reporting is regulated, mandatory, and required to meet certain qualitative characteristics such as relevance, reliability, comparability, materiality, and understandability. In contrast, ESG reporting is not regulated in most parts of the world and does not always meet these criteria. This can lead to greenwashing, where companies exaggerate or misrepresent their 'green' credentials. A global framework for ESG reporting could help to prevent fragmentation,

provide greater comparability and transparency, and reduce the complexity of ESG disclosure, thereby mitigating the risk of greenwashing (De Silva Lokuwaduge & de Silva, n.d.).

Moreover, ESG criteria are increasingly being integrated into investment portfolios to achieve environmental sustainability in the post-COVID-19 era. The interconnectedness between green bonds and ESG assets can provide opportunities for investors to diversify their portfolios and hedge against risks. Investing in green bonds and ESG assets can contribute to the achievement of the United Nations' Sustainable Development Goals and the transition to a low-carbon economy (Hasan et al., 2023).

In conclusion, ESG criteria play a crucial role in green finance by guiding investment decisions towards more sustainable and responsible business practices. However, to fully harness the potential of ESG, there is a need for robust regulatory frameworks, transparency, and effective governance.

Discussion and Conclusion: Reflections and Future Directions for Renewable Energy and the Environment.

Renewable energy has emerged as a promising solution to the world's energy needs, offering the potential to reduce dependence on fossil fuels and mitigate the impacts of climate change. However, as this review has highlighted, the transition to renewable energy is not without its challenges. Striking a balance between renewable energy goals and environmental protection is a complex task that requires careful consideration of a range of factors. Renewable energy technologies, including wind, solar, and nuclear power, have their own unique advantages and disadvantages. Wind and solar power, for instance, are abundant and widely available, but their intermittent nature poses challenges for energy storage and grid integration. Nuclear power, on the other hand, offers a high energy output and low carbon emissions, but concerns about safety and waste disposal remain significant (Zhang et al., 2022; Lejano et al., 2020).

Moreover, the environmental impacts of renewable energy technologies are not negligible. The production and disposal of solar panels, for instance, can lead to significant waste and potential environmental harm. Similarly, wind turbines can have impacts on local ecosystems, including potential effects on bird and bat populations. Nuclear power, while low in carbon emissions, presents challenges in terms of waste disposal and potential environmental contamination (Sun et al., 2023; De Silva Lokuwaduge & de Silva, n.d.). In the realm of green finance, tools such as carbon credits and ESG criteria can incentivize emission reductions and promote sustainable business practices. However, these tools also face challenges, including the risk of greenwashing and the need for robust regulatory frameworks and transparency (Hasan et al., 2023). Looking ahead, it is clear that the transition to renewable energy will require a multifaceted approach that considers not only the energy output and carbon emissions of

different technologies, but also their broader environmental impacts and social implications. Future research should continue to explore innovative solutions and strategies for balancing renewable energy goals with environmental protection.

As the world continues to grapple with the challenges of climate change and energy security, the future of renewable energy and its role in environmental protection is a topic of ongoing debate. Several future scenarios can be envisioned, each with its own implications for the balance between renewable energy goals and environmental protection.

One scenario is the continued expansion of renewable energy technologies, driven by technological advancements and policy support. In this scenario, renewable energy becomes the dominant source of power, significantly reducing greenhouse gas emissions and dependence on fossil fuels. However, this scenario also presents challenges in terms of managing the environmental impacts of renewable energy production and disposal, as well as ensuring the reliability and resilience of the energy system (Zhang et al., 2022).

Another scenario is the development and deployment of new, more sustainable energy technologies. These could include advanced nuclear power technologies, such as fusion power, which offer the potential for high energy output with minimal waste and emissions. Alternatively, new forms of renewable energy, such as tidal or geothermal power, could be developed and deployed on a large scale. These technologies could offer additional options for reducing emissions and diversifying the energy mix, but they also present their own environmental and technical challenges (Lejano et al., 2020).

A third scenario is the integration of energy systems, with a focus on energy efficiency and demand management. In this scenario, the emphasis is not just on producing more renewable

energy, but also on using energy more efficiently and managing demand to reduce the overall need for energy. This could involve the widespread adoption of energy-efficient technologies, the development of smart grids and energy storage solutions, and changes in consumer behavior. This scenario presents opportunities for reducing both emissions and environmental impacts, but it also requires significant changes in infrastructure, policy, and societal behavior (Sun et al., 2023).

The transition to renewable energy presents both opportunities and challenges. Striking a balance between renewable energy goals and environmental protection is a complex task, but one that is crucial for the future of our planet. With careful planning and consideration of the environmental and social impacts of different energy technologies, it is possible to navigate this complex landscape and move towards a more sustainable and resilient energy future.

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