

IJRTS TAKSHILA FOUNDATION

An Edited Book

NEW CHALLENGES IN ENVIRONMENTAL
& SUSTAINABLE ENERGY FOR

GREEN FUTURE



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Chief Editor

Prof. Vijay Aithekar

Assistant Professor, Dept. of Science
Oriental University, Indore, MP 453555, India

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Invited Manuscripts

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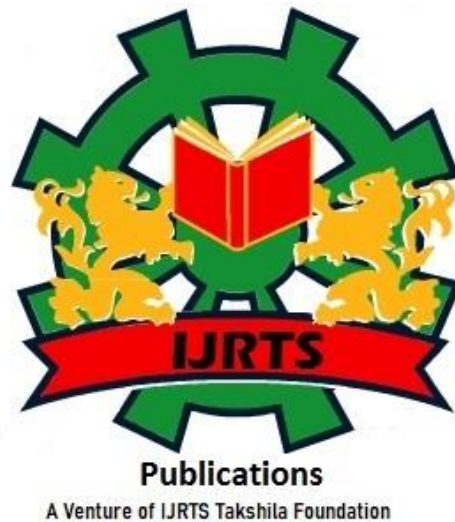
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Preface

As we face growing environmental challenges, the need for sustainable energy solutions has become more urgent than ever. Climate change, resource depletion, and pollution are some of the biggest threats to our planet, and how we produce and use energy plays a central role in these issues. Transitioning to clean and sustainable energy is essential for protecting the environment and ensuring a healthier future for generations to come.

"New Challenges in Environmental & Sustainable Energy for Green Future" aims to explore the various obstacles and opportunities in the journey toward a more sustainable energy system. This book looks at the latest advancements in renewable energy, energy efficiency, and green technologies, while also addressing the barriers that still exist in adopting these solutions. From technical challenges to policy issues, this book covers the wide range of factors that must be considered to achieve a greener and more sustainable energy future.

The purpose of this edited book is to provide readers with a clear understanding of the key challenges and opportunities in the field of sustainable energy. It will discuss the importance of collaboration between governments, industries, researchers, and communities in driving the necessary changes. By highlighting both the progress we've made and the work that still needs to be done, I hope to inspire action and encourage innovative thinking to solve these critical environmental problems.

This edited book is written for anyone interested in learning more about sustainable energy, whether they are students, researchers, industry professionals, or concerned citizens. My hope is that it will help readers understand the importance of sustainable energy in shaping a better future for our planet. I owe the dedication to my mother Late. Smt. Sarla Aithekar.

As we move forward, the decisions we make about energy will have a lasting impact on the environment. This book is a call to action for all of us to work together and find solutions that support a green and sustainable future.

Prof. Vijay Aithekar

Chief Editor

Assistant Professor, Dept. of Science

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Understanding Solar Cell Efficiency at Low Intensity Levels: A Qualitative Examination of Influencing Factors

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Abstract

The transition to renewable energy sources is essential for reducing the environmental impact of fossil fuels such as petroleum and diesel. Photovoltaic (PV) cells are at the forefront of this shift due to their ability to convert sunlight into electricity without harmful emissions. However, despite their benefits, PV cells often exhibit lower efficiency compared to traditional energy sources, leading to higher costs. This review explores various factors that influence the efficiency of solar cells, including installation design, solar module characteristics, and environmental conditions. Addressing these factors is crucial for improving performance, increasing energy output, and reducing costs. Environmental factors such as sunlight intensity and temperature, along with material quality and design innovations, play significant roles in optimizing PV performance. The review also highlights less obvious factors impacting efficiency and underscores the importance of a comprehensive approach to advancing solar technology. By adopting these strategies, PV cells can become more competitive and contribute to sustainable energy solutions.

1. Introduction

Solar photovoltaic (PV) technology represents a significant advancement in reducing reliance on fossil fuels and mitigating carbon emissions. PV cells harness solar energy, providing a sustainable alternative that contributes to reducing environmental damage and improving energy security. Currently, solar power accounts for about 20% of global renewable energy, with significant growth expected in the coming years. Despite their potential, PV cells face challenges related to efficiency, which is influenced by a range of factors including both environmental conditions and technological aspects.

Solar PV efficiency is affected by several parameters, including fill factor, ideal power, and overall performance. Environmental factors such as temperature, moisture, wind speed, light quality, altitude, and atmospheric pressure have a considerable impact on PV cell efficiency. Additionally, less obvious factors like the albedo effect, parasitic resistances, and contamination from sources such as vehicle exhaust and bird droppings also affect performance. Addressing these issues is crucial for optimizing solar cell efficiency and enhancing their overall effectiveness in harnessing solar energy.

2. Impact of Parameters

2.1 Environmental Factors

2.1.1 Solar Cell Temperature: Temperature plays a critical role in the performance of PV cells. As temperatures rise, the band gap of the cell decreases, and the reverse saturation current increases, this can lead to a reduction in output efficiency. Effective cooling solutions are essential to maintain optimal performance and mitigate the adverse effects of high temperatures.

2.1.2 Dust Deposition: Dust accumulation on solar panels can significantly impair their efficiency and fill factor, reducing power output. Regular cleaning is necessary to maintain performance, and the development of low-maintenance panels is essential to address dust-related issues.

2.1.3 Wind Speed: Wind can positively impact PV panel efficiency by aiding in cooling and dust removal. While moderate wind speeds can enhance performance, extreme wind conditions may negatively affect the stability and productivity of solar installations.

2.1.4 Shading Effects: Shading from objects such as trees or buildings can reduce solar module efficiency by creating hotspots and performance issues. To minimize shading effects, proper panel placement and the use of bypass diodes are recommended.

2.1.5 Humidity: High humidity can cause water droplets to form on panels, leading to rust and a reduction in panel lifespan. This, in turn, affects the power, voltage, and current output of the PV system.

2.1.6 Rainfall and Cloud Cover: Cloud cover and rainfall can dramatically reduce solar panel output, with reductions of up to 93% observed on cloudy or rainy days. Effective system design should account for these variability factors to optimize performance.

2.1.7 Irradiance: The intensity of sunlight directly influences PV performance. Sunny conditions enhance the efficiency of solar panels, while cloudy or rainy weather can significantly decrease output.

2.1.8 Color Wavelength Spectrum: The color of light affects solar panel performance. Studies have shown that different color filters can impact the efficiency and voltage output of PV modules, highlighting the importance of optimizing light conditions.

2.1.9 Air Pressure: Air pressure influences photon energy and electron extraction in solar cells. Higher air pressure can improve output voltage and current, thereby enhancing overall efficiency.

2.1.10 Tilt Angle: The tilt angle of solar panels is crucial for maximizing performance. A 45-degree tilt facing south is generally optimal for achieving the best power output, efficiency, and fill factor.

2.2 Solar Module Characteristics

2.2.1 Material Choice: Solar cells are classified into three generations: wafer-based silicon (first generation), thin-film silicon (second generation), and advanced technologies like nanocrystals and perovskites (third generation). Each generation presents unique efficiency levels and manufacturing complexities.

2.2.2 Dust-Free Coating: Applying dust-resistant coatings and implementing regular cleaning practices are essential for preventing dust buildup, which can reduce PV output by up to 30% on a monthly basis.

3. Solar Installation Design Factors

3.1 Maximum Power Point Tracking (MPPT): MPPT inverters optimize solar power performance by adjusting to environmental conditions and ensuring compliance with grid standards. This technology is crucial for maximizing energy harvest from PV systems.

3.2 Tilt Angle and Orientation: The correct tilt angle and orientation of solar modules are essential for efficiency. A tilt angle of 45 degrees facing south is typically optimal for performance.

3.3 Cable Thickness: The thickness of cables connecting solar modules affects system efficiency. Thicker cables reduce voltage drops and resistive losses, which improves overall system performance.

4. Other Hidden Factors

4.1 Albedo Effect: The albedo effect, which measures light reflection from surfaces, impacts solar panel efficiency. High reflectivity can lead to energy loss, reducing the effectiveness of PV cells.

4.2 Parasitic Resistances: Series and shunt resistances in solar cells can affect efficiency. Advances in technology aim to minimize these resistances and improve cell performance.

4.3 Degradation of PV Modules: PV systems typically have a lifespan of 25 years, with performance degradation affecting efficiency over time. Maintaining rated power in the initial years is crucial for long-term performance.

4.4 Mounting: Proper mounting of solar panels, whether on rooftops or the ground, influences system efficiency and stability.

4.5 Potential-Induced Degradation (PID): PID can cause significant output loss and cell damage, especially in ungrounded systems. Addressing PID is vital for maintaining system efficiency.

4.6 Car Exhaust Smoke: Smoke from vehicle exhaust can reduce panel efficiency, highlighting the need for regular maintenance and cleaning.

4.7 Bird Droppings: Bird droppings can damage solar modules and reduce their efficiency. Regular cleaning is necessary to prevent such damage.

4.8 Reflection: Antireflection coatings and rough surfaces on silicon cells can enhance efficiency by minimizing light reflection and increasing light absorption.

4.9 Inverter Efficiency: Inverters are crucial for converting DC to AC power in PV systems. High-efficiency inverters contribute significantly to overall system performance.

5. Impact of Low Intensity on Solar Cells

5.1 Technological Impact: Low sunlight intensity reduces energy conversion efficiency, requiring more materials to produce the same amount of energy. This increases costs and environmental impact.

5.2 Economic Impact: Reduced efficiency at low light levels raises costs per watt and extends payback periods, making solar technology less attractive economically.

5.3 Environmental Impact: Large-scale solar installations needed to compensate for low-intensity conditions can lead to significant land use, potentially disrupting local ecosystems and biodiversity.

5.4 Social Impact: Higher costs and lower returns limit access for low-income households, exacerbating energy disparities. Public perception of solar technology can be influenced by its efficiency and associated costs.

6. Conclusion

This review has examined critical factors affecting the performance of solar PV systems, including temperature, irradiance, tilt angle, and dust accumulation. Effective management of these factors, combined with technological advancements, can enhance solar cell performance. Addressing hidden factors such as the albedo effect and PID is essential for optimizing efficiency. A holistic approach to improving solar technology will make it more competitive and sustainable, contributing to a greener energy future.

Acknowledgment

I extend my sincere gratitude to the Department of Science, Oriental University Indore, and my esteemed guide, Dr. Hasina Adil Mam, for their invaluable support and resources that facilitated the completion of this review.

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Publications

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Ethics in Publishing: Upholding Integrity in Academic Communication

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Abstract

Academic publishing serves as the cornerstone of knowledge dissemination, influencing education, policy, and research across diverse fields. The integrity of this communication process is vital to ensure the reliability and credibility of published work. This paper explores the importance of ethics in academic publishing, highlighting key challenges such as plagiarism, data manipulation, authorship disputes, and conflicts of interest. Additionally, it emphasizes the roles of editors, peer reviewers, and institutions in maintaining ethical standards. The paper concludes by suggesting measures for strengthening ethical practices in scholarly communication, reinforcing the importance of transparency, accountability, and integrity.

Introduction

Academic publishing is the foundation of knowledge dissemination, contributing significantly to the advancement of science, technology, and various fields of study. The ethical responsibilities associated with this process cannot be overstated, as they ensure the integrity and credibility of published research. Unethical practices, such as plagiarism, falsification of data, and conflicts of interest, can tarnish the reputation of both the academic community and the broader scientific enterprise. As the volume of published work continues to grow, so does the need for vigilance in maintaining ethical standards.

This paper discusses the core principles of ethics in publishing, the challenges encountered in upholding these standards, and the key stakeholders responsible for ensuring ethical compliance. It also explores the importance of transparency and accountability in fostering trust within the academic community and the broader public.

Ethical Principles in Academic Publishing

The fundamental principles of ethical academic publishing revolve around honesty, transparency, accountability, and fairness. These principles are essential for preserving the integrity of the scholarly record and ensuring that published work contributes meaningfully to the advancement of knowledge.

1. Honesty and Accuracy

Researchers are expected to present their findings truthfully and accurately, without manipulation or fabrication of data. Misleading or falsified data undermines the credibility of the research and can have serious consequences, such as misinforming future research, policy decisions, or medical practices.

2. Transparency and Disclosure

Transparency is crucial in the publication process. Researchers should disclose any conflicts of interest, funding sources, and affiliations that may influence the study's outcome or interpretation. Similarly, transparency extends to data sharing, where researchers should make their data accessible for verification and replication by other scholars.

3. Fairness in Authorship

The issue of authorship can be a source of ethical tension in academic publishing. Proper credit should be given to individuals who have made significant contributions to the research. Ethical guidelines require that authorship is accurately assigned, and all contributors are fairly acknowledged. Ghostwriting, honorary authorship, and exclusion of deserving contributors violate ethical standards.

4. Peer Review Integrity

The peer review process is central to maintaining the quality and credibility of academic publications. Peer reviewers play a crucial role in evaluating the validity, significance, and originality of research. To ensure ethical integrity, reviewers must maintain confidentiality, provide unbiased feedback, and avoid conflicts of interest that could compromise their objectivity.

Challenges in Upholding Publishing Ethics

While the principles of ethical publishing are well-established, various challenges threaten their consistent application in academic communication. These challenges include plagiarism, data manipulation, conflicts of interest, and the proliferation of predatory journals.

1. Plagiarism and Self-Plagiarism

Plagiarism, or the presentation of another's work as one's own, is a severe violation of ethical publishing standards. It undermines the originality of research and damages the trust that readers place in the scholarly record. Self-plagiarism, where authors republish their own previously published work without proper attribution, is another concern, as it inflates the academic output without contributing new knowledge.

2. Data Fabrication and Manipulation

One of the most serious breaches of ethics in research publishing is the fabrication or manipulation of data. This practice involves altering research results to support desired outcomes, which can mislead readers and researchers who rely on published data. Such actions can cause a ripple effect, with future research building on falsified findings, leading to a cycle of misinformation.

3. Authorship Disputes

Authorship disputes often arise when there is a lack of clarity about the contributions of each individual involved in the research. Unethical practices such as "guest authorship" (granting authorship to individuals who made no significant contribution) or "ghost authorship" (excluding deserving contributors) are common issues that need to be addressed to maintain fairness in the publishing process.

4. Conflicts of Interest

Conflicts of interest occur when personal, financial, or professional relationships could potentially influence the objectivity of the research. Authors, reviewers, and editors must disclose any conflicts of interest to avoid bias in the publication process. When undisclosed conflicts of interest come to light, they can severely damage the credibility of both the research and the journal.

5. Predatory Journals

The rise of predatory journals—publications that prioritize profit over rigorous peer review and ethical standards—poses a significant challenge to academic publishing. These journals often publish low-quality or even fraudulent research, bypassing the safeguards that reputable journals have in place. Researchers, especially those early in their careers, may fall prey to predatory journals due to their aggressive marketing tactics and promises of rapid publication.

The Role of Stakeholders in Maintaining Ethical Standards

The responsibility for maintaining ethical standards in academic publishing does not fall on authors alone. Editors, peer reviewers, academic institutions, and funding bodies all play crucial roles in ensuring the integrity of the scholarly communication process.

1. Editors and Journal Publishers

Editors are gatekeepers of the academic publishing process. They are responsible for ensuring that submitted manuscripts meet ethical standards and are free from plagiarism, data manipulation, and conflicts of interest. Journal publishers must also enforce rigorous peer review procedures and provide clear guidelines on ethical practices for authors, reviewers, and editors.

2. Peer Reviewers

As part of the peer review process, reviewers must evaluate submissions impartially and provide constructive feedback. They should be vigilant in identifying potential ethical issues, such as plagiarism or conflicts of interest, and report any concerns to the journal editor. Reviewers also have an ethical responsibility to maintain confidentiality and avoid any biases that could influence their assessments.

3. Academic Institutions

Universities and research institutions are pivotal in promoting ethical research and publishing practices. They should provide training on research ethics, plagiarism prevention, and proper authorship attribution. Institutions must also have mechanisms in place to investigate allegations of misconduct and take appropriate disciplinary actions when necessary.

4. Funding Bodies

Funding agencies play a key role in shaping the research landscape. By requiring transparency and ethical compliance in grant applications and funded projects, they can ensure that research integrity is upheld. These agencies can also contribute to ethical publishing by mandating data sharing and disclosure of conflicts of interest.

Recommendations for Enhancing Ethical Practices

To strengthen ethical standards in academic publishing, several measures can be implemented:

1. **Clear Ethical Guidelines:** Journals should provide clear and detailed ethical guidelines for authors, reviewers, and editors. These guidelines should outline expectations for transparency, authorship, data sharing, and disclosure of conflicts of interest.
2. **Plagiarism Detection Tools:** Publishers and academic institutions should invest in advanced plagiarism detection tools to identify potential instances of plagiarism before publication.
3. **Education and Training:** Researchers should receive ongoing training in ethical publishing practices, including proper citation, authorship attribution, and data management.
4. **Strengthening Peer Review:** Enhancing the rigor of the peer review process through double-blind reviews and transparent criteria for evaluating manuscripts can help maintain the quality and integrity of published research.
5. **Addressing Predatory Journals:** Academic institutions and funding agencies should raise awareness about predatory journals and provide researchers with resources to identify legitimate outlets for publication.

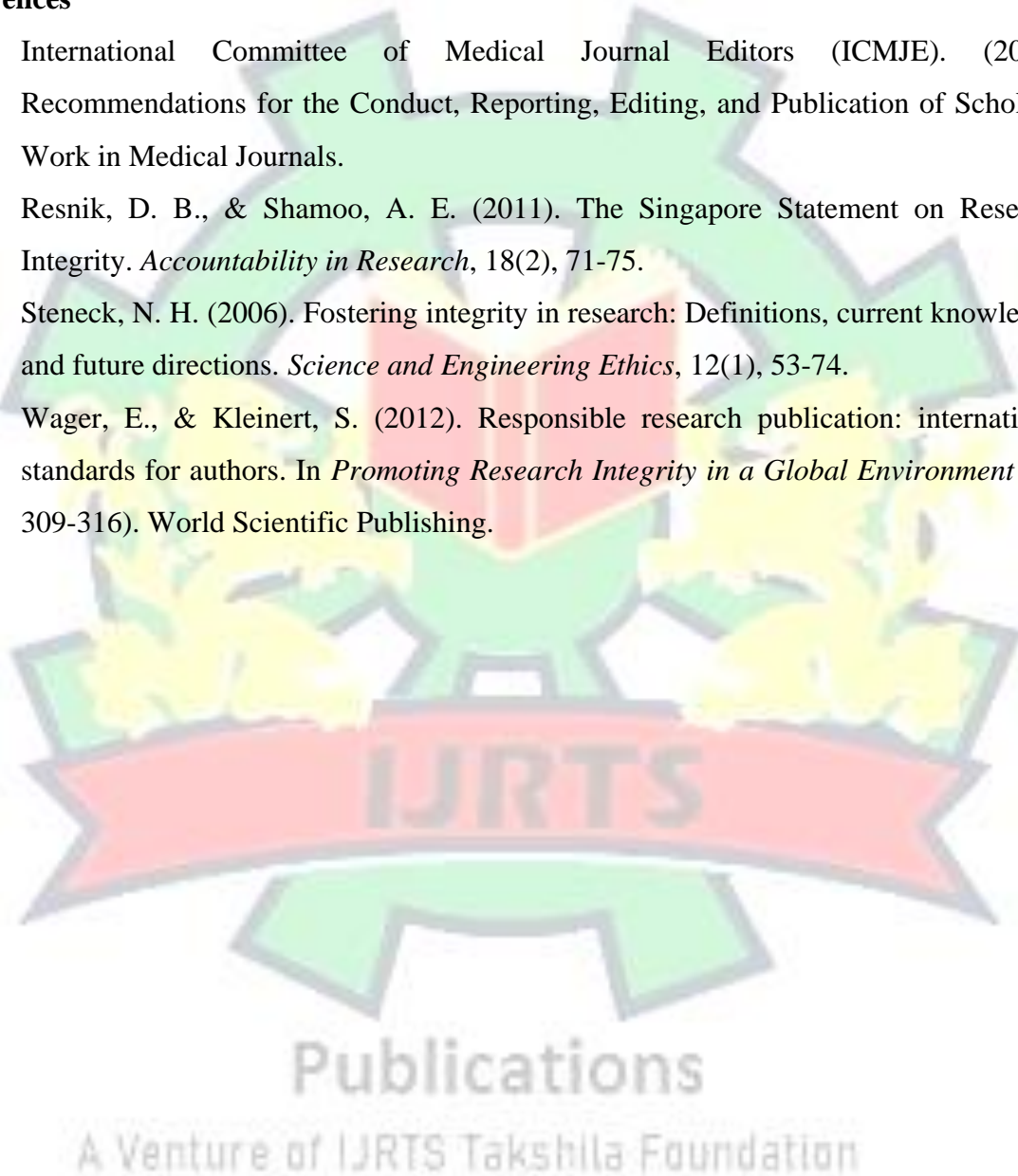
Conclusion

The ethical challenges in academic publishing are multifaceted and demand a collective effort from authors, editors, reviewers, institutions, and funding bodies. Upholding integrity in scholarly communication is essential for the credibility of the academic community and the advancement of knowledge. By adhering to ethical principles, such as transparency, honesty,

and accountability, and by addressing the challenges posed by unethical practices, the academic publishing system can continue to serve as a trusted source of information and innovation. The ongoing commitment to these standards is crucial for fostering trust in research and ensuring that the scientific record remains reliable and robust.

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The Role of Green Synthesized Inhibitors in Environmentally Conscious Metal Protection

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Introduction

The increasing industrial demand for durable materials has underscored the importance of metal alloys in applications ranging from construction to transportation. However, these materials face the persistent challenge of corrosion, which leads to structural failure, economic losses, and environmental damage. Traditional corrosion inhibitors, often chemically synthesized, have been the primary solution to mitigate corrosion. Despite their effectiveness, these inhibitors pose significant environmental and health risks due to their toxicity and non-biodegradability.

Green synthesized corrosion inhibitors, derived from natural sources, have emerged as sustainable alternatives that align with the principles of environmental consciousness. By leveraging naturally occurring compounds, green inhibitors offer a promising solution to reduce the ecological footprint of corrosion prevention. This chapter explores the role of green synthesized inhibitors in environmentally conscious metal protection, examining their mechanisms, benefits, applications, and challenges.

Understanding Green Synthesized Corrosion Inhibitors

Definition and Sources

Green synthesized corrosion inhibitors are derived from renewable natural resources, including plant extracts, algae, agricultural residues, and microbial by-products. These inhibitors typically contain bioactive compounds such as alkaloids, flavonoids, tannins, and saponins, which possess inherent corrosion-inhibiting properties.

Mechanism of Action

Green inhibitors function primarily by forming a protective layer on the metal surface, preventing corrosive agents such as oxygen, water, and chloride ions from initiating the corrosion process. Key mechanisms include:

1. **Adsorption:** Phytochemicals adsorb onto the metal surface, forming a barrier that minimizes exposure to corrosive elements.
2. **Complex Formation:** Bioactive compounds form chelates with metal ions, reducing their reactivity.
3. **Antioxidant Activity:** Natural inhibitors release antioxidants that neutralize reactive species, further inhibiting corrosion.

Benefits of Green Synthesized Corrosion Inhibitors

Environmental Advantages

- **Biodegradability:** Green inhibitors decompose naturally, reducing long-term environmental impact.
- **Low Toxicity:** Derived from natural sources, they pose minimal risk to human health and aquatic ecosystems.

Economic and Practical Benefits

- **Cost-Effectiveness:** Agricultural and industrial by-products can serve as raw materials, lowering production costs.
- **Renewability:** Reliance on natural resources ensures a sustainable supply chain.

Technical Advantages

- **Multifunctionality:** Many green inhibitors also possess antibacterial and antifungal properties, offering additional benefits.
- **Adaptability:** Their efficacy can be enhanced by combining different natural extracts or by modifying their chemical structure.

Applications of Green Synthesized Corrosion Inhibitors

Industrial Use Cases

1. **Oil and Gas Industry:** Protecting pipelines and storage tanks from corrosion caused by harsh environments.
2. **Marine Applications:** Preventing corrosion of ships and offshore platforms exposed to saline conditions.
3. **Construction:** Protecting steel reinforcements in concrete structures from degradation.

Academic and Experimental Applications

- **Electrochemical Studies:** Evaluating the performance of green inhibitors through techniques like electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization.
- **Material Science Research:** Developing hybrid inhibitors by combining green and chemically synthesized materials.

Emerging Fields

- **Biocompatible Coatings:** Using green inhibitors for medical implants to prevent metal degradation and improve biocompatibility.
- **Nanotechnology:** Enhancing inhibitor performance through nano-encapsulation, ensuring controlled release and prolonged protection.

Challenges and Limitations

Performance Variability

The efficacy of green inhibitors depends on the consistency and concentration of bioactive compounds, which can vary based on natural source and extraction methods.

Stability Concerns

Green inhibitors often exhibit lower thermal and chemical stability compared to synthetic alternatives, limiting their applicability in extreme environments.

Scalability and Commercialization

- **Production Challenges:** Extracting and processing natural inhibitors on an industrial scale remains a challenge.
- **Economic Viability:** While cost-effective in small-scale applications, large-scale deployment requires optimization to compete with chemical inhibitors.

Future Directions and Research Opportunities

Advancing Formulation Techniques

- **Hybrid Inhibitors:** Combining green inhibitors with nanomaterials or synthetic compounds to enhance performance and stability.
- **Standardization:** Developing protocols for consistent extraction and characterization of natural compounds.

Expanding Applications

- Exploring the use of green inhibitors in emerging industries, such as renewable energy, where sustainability is a key concern.

Policy and Regulation

- Encouraging adoption through government incentives and stricter regulations on the use of toxic chemical inhibitors.

Conclusion

Green synthesized corrosion inhibitors represent a transformative shift toward environmentally conscious metal protection. By harnessing the power of natural compounds, these inhibitors provide an effective, sustainable alternative to traditional methods. While challenges such as stability and scalability remain, ongoing research and innovation continue to expand their applicability and performance.

As industries increasingly prioritize sustainability, green inhibitors are poised to play a critical role in reducing the environmental impact of corrosion prevention, ensuring a greener and more sustainable future for metal protection.

From Chemicals to Nature: Redefining Corrosion

Inhibition for Sustainable Development

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Introduction

Corrosion is a pervasive issue impacting industries and infrastructure globally. The deterioration of metals due to chemical, electrochemical, or environmental interactions results in substantial economic losses and safety hazards. Traditional approaches to mitigate corrosion have relied heavily on chemically synthesized inhibitors, which, despite their efficacy, often introduce significant environmental and health risks. With the growing emphasis on sustainable development, there is a pressing need to explore eco-friendly alternatives that align with environmental preservation goals.

This chapter examines the shift from conventional chemical inhibitors to green, nature-inspired solutions in corrosion inhibition. It highlights the principles of sustainable development driving this transition, the science behind green inhibitors, their applications, and the challenges of integrating these innovative solutions into industry practices.

The Case for Sustainable Corrosion Inhibition

Environmental and Economic Impacts of Corrosion

- **Global Costs:** Corrosion incurs trillions of dollars in annual losses, representing approximately 3-4% of global GDP.
- **Environmental Damage:** Chemical inhibitors often lead to soil and water contamination due to improper disposal.
- **Health Risks:** Toxic components in conventional inhibitors pose health hazards to workers and surrounding communities.

Principles of Sustainable Development

- **Resource Efficiency:** Utilizing renewable and biodegradable materials.
- **Pollution Prevention:** Minimizing environmental harm through non-toxic solutions.
- **Circular Economy:** Encouraging the reuse of by-products and waste materials for corrosion inhibition.

Green Corrosion Inhibitors: A Nature-Inspired Approach

Sources of Green Inhibitors

Green corrosion inhibitors are derived from natural resources, including:

1. **Plant Extracts:** Rich in bioactive compounds such as tannins, flavonoids, and alkaloids.
2. **Microbial By-Products:** Organic acids and biosurfactants produced by bacteria and fungi.
3. **Agricultural and Industrial Waste:** Utilizing biomass, peel extracts, and other residues.

Mechanisms of Action

Green inhibitors function similarly to chemical inhibitors by forming protective layers on metal surfaces. Their mechanisms include:

- **Adsorption:** Phytochemicals adhere to the metal surface, creating a barrier against corrosive agents.
- **Complex Formation:** Natural compounds bind with metal ions, reducing their reactivity.
- **Antioxidant Properties:** Neutralizing oxidative species to prevent corrosion initiation.

Advantages of Green Inhibitors

- **Eco-Friendliness:** Biodegradable and non-toxic, they have minimal ecological impact.

- **Cost-Effectiveness:** Readily available raw materials reduce production costs.
- **Multifunctionality:** Some inhibitors also exhibit antimicrobial and UV-protective properties.

Applications of Green Corrosion Inhibitors

Industrial Sectors

1. **Oil and Gas:** Preventing corrosion in pipelines and storage tanks exposed to harsh chemicals.
2. **Construction:** Protecting steel reinforcements in concrete structures.
3. **Marine Environments:** Safeguarding ships and offshore platforms from saltwater-induced corrosion.

Emerging Technologies

- **Nanotechnology Integration:** Nano-encapsulation of green inhibitors enhances stability and controlled release.
- **Hybrid Solutions:** Combining green inhibitors with conventional ones to achieve superior performance.

Case Studies

1. **Neem Extracts in Steel Protection:** Studies have shown neem leaf extracts effectively reduce corrosion rates in acidic environments.
2. **Algae-Derived Compounds:** Algal polysaccharides have demonstrated significant potential in inhibiting corrosion in saline conditions.

Challenges in Transitioning to Green Solutions

Scientific Challenges

- **Performance Variability:** Natural sources exhibit inconsistent composition, affecting inhibitor efficacy.
- **Stability Issues:** Green inhibitors often lack thermal and chemical stability.

Industrial Challenges

- **Scalability:** Difficulty in producing inhibitors on an industrial scale while maintaining cost efficiency.
- **Compatibility:** Ensuring green inhibitors are compatible with existing corrosion prevention systems.

Regulatory and Economic Barriers

- **Lack of Standards:** Absence of universally accepted protocols for testing and evaluating green inhibitors.
- **Market Acceptance:** Convincing industries to adopt new solutions despite the higher initial investment.

Future Directions

Research Opportunities

- **Bioengineering:** Developing genetically modified organisms to produce highly effective inhibitors.
- **Advanced Characterization:** Using AI and machine learning to analyze and predict inhibitor performance.

Policy and Regulation

- Encouraging the adoption of green inhibitors through subsidies and stricter regulations on chemical inhibitors.

Collaboration and Knowledge Sharing

- Building partnerships between academia, industry, and government to accelerate innovation and adoption.

Conclusion

The transition from chemically synthesized inhibitors to nature-inspired solutions represents a pivotal step toward sustainable development. Green inhibitors offer a promising alternative,

balancing efficacy with environmental responsibility. While challenges remain, continued research, innovation, and collaboration can pave the way for a greener, corrosion-free future.

This chapter underscores the importance of redefining corrosion inhibition strategies to align with sustainability goals, ensuring that industrial progress does not come at the expense of environmental health.



Publications

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Overcoming Barriers: Addressing Challenges in Environmental and Sustainable Energy for a Green Future

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Introduction

The global transition toward sustainable energy is no longer a choice but a necessity. As climate change, environmental degradation, and finite fossil fuel reserves threaten the planet's future, renewable and sustainable energy sources have become central to global policy and innovation. However, the road to a green future is fraught with challenges. From technological limitations and economic constraints to policy bottlenecks and societal resistance, overcoming these barriers requires coordinated efforts across industries, governments, and communities.

This chapter explores the key challenges in achieving a green energy future and outlines strategies to address these barriers effectively. By examining technological, economic, political, and social dimensions, it aims to provide a roadmap for advancing sustainable energy solutions.

Technological Challenges and Solutions

Challenge: Energy Storage and Grid Integration

Renewable energy sources like solar and wind are intermittent, creating challenges in ensuring a stable energy supply.

- **Current Barrier:** Lack of efficient and affordable large-scale energy storage solutions.
- **Potential Solutions:**
 - Advancing battery technologies such as solid-state and flow batteries.

- Exploring alternative storage methods, including hydrogen fuel cells and compressed air energy storage.
- Developing smart grids capable of dynamic energy distribution and integration with diverse energy sources.

Challenge: Efficiency of Renewable Technologies

While renewable technologies have made significant strides, their efficiency often lags behind traditional energy systems.

- **Current Barrier:** High initial costs and lower conversion efficiencies for solar panels, wind turbines, and bioenergy systems.
- **Potential Solutions:**
 - Enhancing material science research to improve photovoltaic and turbine technologies.
 - Investing in advanced manufacturing techniques to reduce production costs.
 - Promoting innovation through collaborative research initiatives.

Challenge: Infrastructure Development

- **Current Barrier:** Inadequate infrastructure to support the widespread adoption of renewable energy.
- **Potential Solutions:**
 - Building decentralized microgrids to enhance rural energy access.
 - Upgrading transmission lines to handle increased renewable energy loads.
 - Encouraging public-private partnerships to accelerate infrastructure investment.

Economic and Financial Barriers

Challenge: High Upfront Costs

Transitioning to renewable energy often requires significant initial investments, which can deter adoption.

- **Current Barrier:** Limited access to financing for renewable energy projects.
- **Potential Solutions:**
 - Establishing green banks and funds to provide low-interest loans.
 - Offering subsidies and tax incentives to lower investment barriers for businesses and households.
 - Encouraging global financing institutions to prioritize renewable energy investments.

Challenge: Market Dynamics and Fossil Fuel Dependence

- **Current Barrier:** Fossil fuels remain heavily subsidized, making renewables less competitive.
- **Potential Solutions:**
 - Phasing out fossil fuel subsidies to create a level playing field.
 - Introducing carbon pricing mechanisms to incentivize clean energy adoption.
 - Promoting energy diversification to reduce dependency on single energy sources.

Policy and Regulatory Challenges

Challenge: Inconsistent Policies and Regulatory Frameworks

The absence of uniform policies hampers large-scale adoption and innovation in sustainable energy.

- **Current Barrier:** Fragmented regulatory environments across regions.
- **Potential Solutions:**
 - Establishing global and regional agreements on renewable energy targets.

- Creating flexible policies that adapt to technological advancements and market changes.
- Streamlining permitting processes for renewable energy projects.

Challenge: Political Resistance

- **Current Barrier:** Resistance from vested interests in traditional energy sectors.
- **Potential Solutions:**
 - Building coalitions that align political interests with environmental goals.
 - Increasing public awareness to drive political accountability.
 - Strengthening international collaborations to counter resistance at local levels.

Social and Behavioral Challenges

Challenge: Public Acceptance and Awareness

Societal resistance to change and lack of awareness can slow the adoption of renewable energy technologies.

- **Current Barrier:** Misconceptions about the reliability and cost of renewable energy.
- **Potential Solutions:**
 - Implementing educational campaigns to promote renewable energy benefits.
 - Involving local communities in decision-making processes.
 - Demonstrating the long-term economic and environmental gains of renewables.

Challenge: Equity and Accessibility

Ensuring equitable access to renewable energy solutions remains a critical issue.

- **Current Barrier:** Disparities in renewable energy deployment between urban and rural areas.

- **Potential Solutions:**

- Developing tailored policies to address energy poverty.
- Supporting decentralized energy systems to empower remote communities.
- Ensuring fair pricing models that make renewable energy affordable for all.

Emerging Trends and Opportunities

Technological Innovations

- Exploring breakthroughs in AI and IoT for energy management.
- Advancing fusion energy research as a long-term sustainable energy source.

Collaborative Models

- Encouraging cross-sector partnerships to accelerate innovation.
- Building global alliances for knowledge sharing and resource pooling.

Policy Momentum

- Harnessing the momentum from international agreements like the Paris Accord.
- Strengthening commitments to net-zero emissions through enforceable policies.

Conclusion

The journey to a green future is complex but achievable. Addressing the technological, economic, policy, and social barriers to sustainable energy requires a multifaceted approach involving innovation, collaboration, and commitment. By overcoming these challenges, we can transition to an energy system that not only meets our needs but also safeguards the planet for future generations.

This chapter emphasizes the importance of collective action and continued investment in overcoming barriers to sustainable energy. Together, we can create a resilient, equitable, and green future powered by renewable energy.

The Role of AI in Achieving Sustainable Energy

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Introduction

The global demand for energy is on the rise, driven by population growth, urbanization, and the increasing reliance on digital technologies. As the world continues to grapple with the challenges posed by climate change, achieving sustainable energy solutions has become more critical than ever. One of the most promising advancements in this area is the integration of Artificial Intelligence (AI). AI has the potential to revolutionize how we generate, manage, and consume energy, optimizing processes that were once inefficient or labor-intensive. This chapter explores the role of AI in promoting sustainable energy solutions, focusing on its applications, benefits, and the challenges that come with its adoption.

1. Understanding Sustainable Energy

Sustainable energy refers to energy sources that meet present needs without compromising the ability of future generations to meet their own needs. This includes renewable sources such as solar, wind, hydro, and geothermal energy, as well as improvements in energy efficiency and energy storage. The key objectives of sustainable energy systems are to reduce carbon emissions, lower costs, and minimize environmental impacts while ensuring reliable and equitable access to energy.

2. How AI Enhances Energy Generation

AI plays a pivotal role in transforming energy generation, especially in renewable energy sectors like solar and wind. By leveraging machine learning algorithms and real-time data analytics, AI can optimize the operation and output of renewable energy systems, making them more efficient and cost-effective.

a. Wind Energy Optimization

Wind farms are subject to variations in wind speed and direction, which can impact energy generation. AI-powered systems can predict weather patterns and adjust turbine settings accordingly. For instance, predictive models powered by AI can forecast wind speeds and optimize turbine operations to ensure maximum energy output while preventing damage from extreme conditions. Furthermore, AI algorithms can be used to predict the lifespan of turbines, allowing for better maintenance schedules and reducing operational downtime.

b. Solar Energy Optimization

AI can be used to enhance the performance of solar energy systems by predicting and optimizing the angle of solar panels. By integrating real-time weather data and historical sunlight patterns, AI can calculate the optimal positioning for solar panels to maximize energy absorption. Additionally, AI algorithms can monitor the health of solar panels, identify malfunctioning components, and suggest maintenance actions before problems lead to significant energy loss.

c. Grid Integration of Renewables

The integration of renewable energy sources into the grid is one of the biggest challenges in achieving sustainable energy. Renewables are inherently intermittent—solar and wind energy fluctuate depending on weather conditions, making it difficult to maintain a stable supply of electricity. AI can help manage these fluctuations by predicting energy demand and supply in real-time, balancing the load, and optimizing the distribution of energy across the grid. AI-powered smart grids can also store excess energy generated during peak production times and release it when demand is high, ensuring a continuous and reliable energy supply.

3. AI in Energy Storage and Battery Management

One of the key challenges in renewable energy is energy storage. Unlike fossil fuels, which can be stored and used when needed, renewable energy sources like wind and solar are often generated during specific periods and may not align with peak demand times. AI is playing a significant role in overcoming this challenge by improving energy storage systems, such as batteries.

a. Optimizing Battery Storage

AI systems can predict energy consumption patterns and store excess energy at optimal times. Machine learning algorithms can analyze vast amounts of data on energy use, weather patterns, and battery performance to determine the most efficient charging and discharging cycles for energy storage systems. By doing so, AI ensures that energy storage systems are used to their maximum capacity, thus enhancing the overall efficiency of renewable energy systems.

b. Battery Health Management

Battery life is a critical factor in the success of energy storage solutions. AI can continuously monitor the health of batteries, detecting early signs of degradation and optimizing the charging and discharging processes to extend their lifespan. This predictive maintenance approach helps prevent costly replacements and ensures the longevity of storage systems, making renewable energy more reliable and affordable.

4. AI in Demand Response and Energy Efficiency

AI has a crucial role to play in improving energy efficiency across various sectors, from residential to industrial applications. By using AI-powered systems, energy consumption can be optimized in real-time, reducing waste and ensuring that energy is used only when necessary.

a. Smart Homes and Buildings

In residential and commercial buildings, AI can manage heating, cooling, and lighting systems to ensure that energy is used efficiently. AI-based smart thermostats and energy management systems can learn occupants' preferences and adjust energy consumption based on real-time data such as occupancy and weather forecasts. By automating these systems, AI ensures that energy is not wasted when rooms are unoccupied, leading to significant cost savings and a reduced carbon footprint.

b. Industrial Energy Efficiency

In industrial settings, AI can be used to optimize manufacturing processes, reducing energy consumption while maintaining productivity. AI systems can analyze production data, identify energy waste, and suggest changes to reduce consumption. Predictive maintenance

enabled by AI can also help ensure that industrial equipment operates at peak efficiency, further minimizing energy waste.

c. Energy Consumption Forecasting

AI can analyze historical data to forecast energy consumption patterns and provide real-time insights into how energy is being used. By combining machine learning with predictive analytics, AI can optimize energy use, reducing peak demand and avoiding unnecessary strain on the grid. This can significantly reduce energy costs while contributing to a more sustainable energy future.

5. AI for Decentralized Energy Systems

As the world moves toward decentralized energy systems, where consumers generate and store their own energy, AI can facilitate the efficient management of these systems. AI can enable peer-to-peer energy trading, allowing consumers to buy and sell energy within local communities. Machine learning algorithms can be used to balance supply and demand across decentralized networks, ensuring that energy is distributed efficiently, minimizing waste, and promoting the use of renewable energy.

6. AI's Role in Energy Policy and Planning

AI also plays a critical role in informing energy policy and planning. By analyzing vast amounts of data from energy markets, weather systems, and technological trends, AI can provide insights that help policymakers make informed decisions about energy infrastructure, renewable energy investments, and regulatory frameworks. Machine learning models can also simulate different scenarios, helping planners understand the potential impacts of various energy policies on sustainability and economic development.

7. Challenges and Ethical Considerations

While AI offers immense potential for advancing sustainable energy, there are challenges and ethical considerations that must be addressed. These include data privacy, the need for robust cybersecurity measures, and the environmental impact of AI systems themselves. Training AI models requires significant computational resources, which can contribute to carbon emissions if not powered by renewable energy sources. Furthermore, there are concerns about

the equity of AI solutions, ensuring that benefits are accessible to all, particularly in developing regions.

Conclusion

AI has the potential to be a game-changer in the quest for sustainable energy. By optimizing energy generation, storage, and consumption, AI can help reduce carbon emissions, improve efficiency, and lower costs. As AI technology continues to evolve, it will play an increasingly important role in shaping the future of global energy systems. However, to fully realize its potential, there is a need for continued research, innovation, and careful consideration of the challenges and ethical implications associated with its deployment. The future of sustainable energy lies at the intersection of cutting-edge technology and responsible stewardship of the planet's resources.





An Edited Book

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