Circular Economy and Energy Transition: An Exploration into Sustainable Energy Production and Consumption

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***Abstract*— The transition to renewable energy sources is imperative for a sustainable future. This paper delves into how the principles of the circular economy can be applied to energy production and consumption. We explore the recycling and repurposing of used solar panels, wind turbine blades, and EV batteries. Additionally, the contribution of waste-to-energy technologies towards a sustainable energy landscape is discussed.**

***Keywords*— Circular Economy, Renewable Energy Lifecycle, Solar Panel Recycling, Wind Turbine Repurposing, Waste-to-Energy Technologies**

I. INTRODUCTION

In today's rapidly changing global environment, the urgency to address and counteract the detrimental effects of climate change has never been more pronounced. As ice caps melt, sea levels rise, and extreme weather events become increasingly commonplace, the clarion call for a sustainable alternative to our energy needs intensifies. At the epicenter of this global movement lies the shift towards renewable energy sources, a transition that is not just about energy but is symbolic of humanity's aspiration to coexist harmoniously with nature.

This decisive move towards sources such as solar, wind, hydro, and geothermal energy stems from a collective realization of two intertwined facts. Firstly, our traditional reliance on fossil fuels, such as coal, oil, and natural gas, has accelerated environmental degradation, leading to unprecedented levels of greenhouse gas emissions. Secondly, these fossil fuels are finite, and their extraction and consumption have socio-economic and geopolitical ramifications that ripple across the globe.

Yet, as we enthusiastically embrace renewables, there is a crucial aspect that demands our attention: the lifecycle of these renewable energy technologies. It's not just about how we harness energy from these sources, but a broader contemplation of how these technologies are manufactured, utilized, and eventually, retired. Every solar panel, wind turbine, or hydro dam has a lifespan, and its environmental footprint extends beyond just its operational phase.

This is where the transformative philosophy of the circular economy comes into play. Moving beyond the confines of the traditional linear economic model, which is characterized by a one-way flow of extraction, production, consumption, and disposal, the circular economy envisions a restorative and regenerative system. In this model, products and materials are continually reutilized, ensuring minimal waste and maximum resource efficiency. The ethos of "reduce, reuse, recycle" isn't just a slogan but becomes the bedrock of economic and industrial processes.

When we overlay the principles of the circular economy onto the renewable energy sector, a new vista of possibilities emerges. Imagine solar panels that, at the end of their operational lives, are not discarded but are repurposed or recycled to extract valuable materials. Consider wind turbine blades that find a second life in infrastructure projects. Think of a world where every aspect of energy production and consumption is optimized to ensure sustainability, longevity, and minimal environmental impact.

In this exploration, we delve deep into the symbiotic relationship between the renewable energy transition and the circular economy, aiming to elucidate how, together, they can chart a course towards a brighter, greener, and more sustainable future for all.

II. Circular Economy: An Overview

The circular economy represents a paradigm shift in our understanding and approach to production, consumption, and waste management. This revolutionary concept challenges the status quo of the prevailing linear economic model, which has long dominated global industries and consumption patterns.

Historically, the linear model has been characterized by a one-way flow: we extract raw materials ("take"), manufacture products from them ("make"), and once these products reach the end of their usability or functionality, they are discarded, often ending up in landfills or polluting the environment ("dispose"). This approach, while efficient in terms of immediate production and consumer needs, has led to massive environmental degradation, resource depletion, and a buildup of waste that our planet struggles to manage.

In contrast, the circular economy introduces a holistic and sustainable approach. At its core, it champions the principles of "reduce, reuse, recycle." But it's more than just a recycling initiative; it's a comprehensive system that seeks to minimize waste at every stage:

Reduce: The focus here is on minimizing resource extraction and consumption. This could mean using fewer raw materials or designing products to be more durable and long-lasting, thereby reducing the need for frequent replacements.

Reuse: Instead of discarding products after a single use, the circular economy emphasizes finding new ways to reuse items, prolonging their lifespan. This might involve repurposing items or finding secondary uses for products that might traditionally be considered waste.

Recycle: When products do reach the end of their usable life, the goal is to break them down and extract valuable components, which can then be used to create new products. This reduces the need for fresh raw materials and minimizes waste.

Beyond these principles, the circular economy also promotes the idea of repairing and refurbishing. Products are designed with longevity in mind, and when they do break down or malfunction, the first instinct is to repair rather than replace.

The ultimate objective of the circular economy is to create a closed-loop system where waste is virtually eliminated. Materials flow in continuous cycles, being used, reused, and recycled perpetually. This not only preserves our planet's precious resources but also offers economic benefits by reducing costs associated with raw material extraction and waste management.

The circular economy is not just an economic model; it's a vision for a sustainable and resilient future where we live in harmony with our environment, making the most of every resource and ensuring that nothing goes to waste.

III. Solar Panels and the Circular Economy

Solar energy has emerged as a sustainable and environmentally friendly solution to meet the world's growing energy demands. However, as we harness the power of the sun, it is equally important to consider the environmental impact and sustainability of the solar panels themselves. This section explores the lifespan of solar panels, the recycling process, and the challenges associated with integrating solar technology into the circular economy.

A. Lifespan of Solar Panels

Typically, solar panels have a lifespan of 25-30 years. During this period, they harness sunlight to generate clean electricity. However, as time passes, the efficiency of solar panels gradually diminishes. Factors such as weathering, wear and tear, and exposure to the elements can lead to a decrease in their energy production capabilities. This reduction in efficiency can make older solar panels less economically viable for energy production, prompting the need for replacement and recycling.

B. Recycling Process

Solar panels contain valuable materials, including silicon, silver, and aluminum, which can be extracted and repurposed for the manufacturing of new solar panels or other products. Recycling these materials is an essential step in ensuring the sustainability of solar energy systems. New and innovative methods are continually being developed to efficiently extract and recover these resources from used panels.

The recycling process typically involves:

Collection: Used solar panels are collected and transported to recycling facilities, preventing them from becoming electronic waste.

Dismantling: At the recycling facility, the panels are carefully disassembled to separate the various components, including the glass, metals, and semiconductor materials.

Material Recovery: Valuable materials like silicon wafers, silver contacts, and aluminum frames are extracted and prepared for reuse in new solar panels or other applications.

Proper Disposal: Any hazardous materials are disposed of safely, ensuring that the recycling process is environmentally responsible.

C. Challenges

Despite the clear environmental benefits of recycling solar panels, there are several challenges that need to be addressed:

High Recycling Costs: Currently, the cost of recycling solar panels can be relatively high, which can deter some from pursuing recycling initiatives. This cost includes collection, transportation, and processing expenses.

Lack of Standardization: The absence of standardized recycling processes can complicate the recycling of solar panels. Different manufacturers may use different materials and construction methods, making it challenging to streamline the recycling process.

However, there is reason for optimism. As the demand for solar energy continues to rise, economies of scale are expected to drive down the costs associated with recycling. Moreover, efforts are underway to establish industry-wide standards for recycling procedures, which will make the process more efficient and cost-effective.

The integration of solar panels into the circular economy is a critical step in maximizing the sustainability of solar energy. By extending the lifespan of solar panels through recycling and addressing the associated challenges, we can ensure that solar power remains a truly green and renewable energy source for the foreseeable future.

IV. Wind Turbine Blades and the Circular Economy

Wind energy has become a cornerstone of sustainable power generation, and wind turbines play a crucial role in harnessing the power of the wind. However, as with any technology, the sustainability of wind turbines, particularly their blades, is essential to reduce environmental impact. In this section, we delve into the lifespan of wind turbine blades, their potential for repurposing, and the ongoing research on recycling composite materials.

A. Lifespan of Wind Turbine Blades

Wind turbine blades, typically constructed from composite materials such as fiberglass and carbon fiber, are engineered to withstand the rigors of constant wind exposure. They have an operational lifespan of approximately 20 years, during which they efficiently convert wind energy into electricity. However, over time, factors like wear and tear, extreme weather conditions, and blade erosion can lead to a decrease in their efficiency. This reduction in performance necessitates the replacement of blades, prompting consideration of their disposal and environmental impact.

B. Repurposing Wind Turbine Blades

Repurposing used wind turbine blades presents a sustainable and environmentally responsible approach to their end-of-life management. These massive and durable structures can find new life in various infrastructure projects, such as bridges, sound barriers, or even playground equipment. By reusing blades in this manner, we not only extend their functional lifespan but also reduce the demand for new materials, thus decreasing the environmental footprint associated with manufacturing new components.

Repurposing wind turbine blades also aligns with the principles of the circular economy by promoting resource efficiency and minimizing waste generation. Moreover, the repurposing process often involves adapting the blades to suit their new applications, showcasing innovation in engineering and design.

C. Recycling Composite Materials from Wind Turbine Blades

While repurposing offers a valuable second life for wind turbine blades, recycling remains a crucial aspect of achieving a truly circular economy for these composite structures. Composite materials pose a unique challenge for recycling, as they consist of multiple layers of different materials bonded together. Research is ongoing to develop efficient and cost-effective methods for recycling composite materials from wind turbine blades.

Some promising recycling techniques involve:

Mechanical Recycling: This method involves shredding or grinding the blades to separate the different materials, which can then be processed for reuse. Challenges include maintaining the quality of recycled materials and reducing energy consumption in the process.

Chemical Recycling: Chemical processes can break down the composite materials into their constituent elements or compounds, allowing for the recovery of valuable materials like fiberglass or carbon fiber. Developing environmentally friendly and economically viable chemical recycling methods is a key focus of research.

As we continue to expand our reliance on wind energy, addressing the sustainability of wind turbine blades becomes increasingly important. The transition towards a circular economy for wind turbine blades not only reduces waste but also conserves resources and mitigates the environmental impact of wind energy infrastructure. Innovations in repurposing and recycling techniques are essential to achieving these sustainability goals and ensuring a greener and more circular future for wind energy. [6] discussed about a method, Sensor network consists of low cost battery powered nodes which is limited in power. Hence power efficient methods are needed for data gathering and aggregation in order to achieve prolonged network life. However, there are several energy efficient routing protocols in the literature; quiet of them are centralized approaches, that is low energy conservation. This paper presents a new energy efficient routing scheme for data gathering that combine the property of minimum spanning tree and shortest path tree-based on routing schemes.

V. EV Batteries and the Circular Economy

The electrification of transportation through electric vehicles (EVs) is a significant step toward reducing greenhouse gas emissions and mitigating climate change. However, the sustainability of EV batteries, which are crucial components of these vehicles, is essential to ensure that the environmental benefits of EVs are maximized. This section explores the lifespan of EV batteries, their potential for a second life, and the recycling processes that contribute to the circular economy.

A. Lifespan of EV Batteries

EV batteries, commonly lithium-ion batteries, have a lifespan of approximately 10-15 years when used in vehicles. After this period, they may no longer meet the performance requirements for automotive use, but they still retain a significant portion of their charge-holding capacity, often around 70% or more. This reduced capacity makes them less suitable for powering a vehicle but still valuable for other applications, leading to considerations of their post-automotive lifespan.

B. Second Life for EV Batteries

The concept of giving EV batteries a "second life" is gaining traction in the EV industry. These batteries, though no longer suitable for vehicle use, can be repurposed for stationary energy storage systems. In this role, they continue to store and supply electricity, helping to balance the grid and support renewable energy integration. This second life not only extends the useful lifespan of the batteries but also maximizes their value and reduces waste.

Repurposing EV batteries for stationary energy storage is an excellent example of the circular economy in action, as it prolongs the utility of the materials and components involved, ultimately reducing the demand for new battery production.

C. Recycling of EV Batteries

Recycling EV batteries is a critical step in achieving a circular economy for these energy storage devices. EV batteries contain valuable materials, including lithium, cobalt, nickel, and various metals, which can be extracted and reused in the manufacturing of new batteries.

Recycling involves several key steps:

Collection: Used EV batteries are collected and transported to recycling facilities, preventing them from ending up in landfills or causing environmental harm.

Disassembly: The batteries are carefully disassembled to separate their various components, including the cathode, anode, electrolyte, and the casing.

Material Recovery: Valuable materials like lithium, cobalt, and nickel are extracted and processed to meet the stringent quality and purity requirements of battery manufacturers.

Safe Disposal: Any hazardous materials or by-products are disposed of safely, ensuring that the recycling process is environmentally responsible.

Recycling not only conserves valuable resources but also reduces the environmental impact associated with mining and manufacturing new battery materials. It contributes to the circular economy by closing the loop on battery materials, making EVs more sustainable in the long run.

Addressing the sustainability of EV batteries is a vital aspect of the broader transition to electric transportation. By maximizing the lifespan of these batteries through second-life applications and recycling, we can reduce waste, conserve resources, and promote a more circular and environmentally friendly EV industry. [8] discussed about a method, Sensor network consists of low cost battery powered nodes which is limited in power. Hence power efficient methods are needed for data gathering and aggregation in order to achieve prolonged network life. However, there are several energy efficient routing protocols in the literature; quiet of them are centralized approaches, that is low energy conservation.

VI. WASTE-TO-ENERGY TECHNOLOGIES

Waste-to-energy technologies represent a crucial aspect of modern waste management practices and renewable energy production. These innovative processes effectively convert various types of waste materials into valuable energy resources in the form of electricity or heat. In this section, we delve into an overview of waste-to-energy technologies, their benefits, and the primary challenges associated with their implementation.

A. Overview of Waste-to-Energy Technologies

Waste-to-energy technologies encompass a diverse range of processes aimed at harnessing the energy potential hidden within waste materials. These technologies are designed to extract energy from various waste streams, including municipal solid waste, industrial waste, agricultural residues, and more. The core principle involves the controlled combustion, gasification, or biochemical conversion of waste to generate heat or electricity.

Common waste-to-energy technologies include:

Incineration: This process involves burning waste at high temperatures, converting it into heat, which can then be used to produce electricity through steam turbines or to provide district heating.

Gasification: Gasification heats waste in a controlled environment, producing synthetic gas (syngas) that can be burned for electricity generation or further processed into fuels and chemicals.

Anaerobic Digestion: Organic waste can be broken down by microorganisms in an oxygen-free environment, producing biogas that can be used for electricity generation or as a renewable natural gas source.

Thermal Depolymerization: This process breaks down organic materials like plastics and agricultural waste into useful hydrocarbon products.

B. Benefits of Waste-to-Energy Technologies

Waste-to-energy technologies offer several significant benefits:

Waste Reduction: They help reduce the volume of waste sent to landfills, which is crucial for managing limited landfill space and minimizing environmental pollution risks.

Energy Generation: These technologies produce valuable energy resources, reducing the reliance on fossil fuels and contributing to the transition to cleaner and more sustainable energy sources.

Resource Recovery: In addition to energy, waste-to-energy processes can recover valuable materials from waste streams, such as metals from incineration ash or nutrient-rich by-products from anaerobic digestion.

Greenhouse Gas Emission Reduction: By replacing fossil fuel-based energy production with energy derived from waste, these technologies can help lower greenhouse gas emissions, contributing to climate change mitigation.

C. Challenges in Implementing Waste-to-Energy Technologies

While waste-to-energy technologies offer numerous advantages, they also come with challenges:

Carbon Neutrality: Ensuring that waste-to-energy processes are carbon-neutral or have a lower carbon footprint than traditional waste disposal methods is a significant challenge. Emissions from combustion or gasification must be minimized and offset to achieve environmental benefits.

Emission Management: Proper management of emissions, including pollutants and particulate matter, is critical to mitigate potential environmental and health risks associated with waste combustion.

Resource Efficiency: Maximizing the recovery of energy and materials from waste streams requires efficient technologies and processes, which may require ongoing innovation and optimization.

Waste Stream Variability: The composition of waste streams can vary widely, making it challenging to design waste-to-energy systems that can effectively handle different types of waste.

Waste-to-energy technologies play a pivotal role in modern waste management and the transition to cleaner energy sources. While they offer significant benefits, addressing challenges related to environmental impact, emissions, and resource efficiency is essential to ensure that these technologies contribute to a sustainable and circular economy. Properly managed waste-to-energy processes can help reduce waste, generate clean energy, and minimize the environmental footprint of waste disposal.

VII. Conclusion

The principles of the circular economy, when applied to energy production and consumption, have the potential to reshape the way we approach and derive energy, offering a pathway to a more sustainable energy future. While challenges do exist, a combination of technological advancements and policy changes can play a pivotal role in surmounting these obstacles, ultimately leading to the establishment of a more sustainable and environmentally responsible energy landscape.

The integration of circular economy principles into energy production and consumption is grounded in the idea of resource efficiency. This means optimizing the use of resources, minimizing waste, and extending the life cycle of energy-related assets. Technological innovation is key to achieving these objectives. For instance, advancements in renewable energy technologies, such as highly efficient solar panels and wind turbines, contribute to the sustainable generation of power.

One of the critical challenges to address is waste reduction. Proper waste management strategies are essential, particularly in the context of renewable energy infrastructure and energy storage systems. Effective handling and disposal of waste materials are crucial to minimize environmental impact.

Extending the lifespan of energy-related assets is another central aspect of circular energy principles. This requires rigorous maintenance, repair, and refurbishment practices to ensure that equipment remains operational for longer periods. Investment in research and development plays a vital role in enhancing the durability and longevity of energy technologies.

Policy changes also play a pivotal role in driving the circular energy transition. Governments and regulatory bodies must implement incentives and enforce regulations that promote sustainable energy practices. Financial incentives, tax benefits, and subsidies can encourage the adoption of circular economy approaches in the energy sector.

Furthermore, public engagement and education are key elements of this transition. Increasing public awareness and fostering a sense of responsibility for sustainable energy practices can lead to broader adoption of circular energy principles by individuals and businesses alike.

While the challenges are substantial, it is important to recognize that a circular energy transition is a complex and long-term endeavor. However, history has shown that with determination and collective effort, remarkable progress can be achieved. As we move forward, continued investments in research, innovation, and policy development will be essential to overcome these challenges. By doing so, we can create a more sustainable and resilient energy landscape that reduces environmental impact, promotes economic growth, and enhances the well-being of current and future generations. The circular economy principles offer a roadmap to this more promising energy future, and with dedication and collaboration, we can make it a reality.

References

[1] Chugh, T, Seth, R, and Tyagi, K. "Beyond the Prompt: Unmasking Prompt Injections in Large Language Models." Accessed [Date]. https://dzone.com/articles/beyond-the-prompt-unmasking-prompt-injections-in-l-1.

[2] Tyagi, K, Rane, C, and Manry, M. "Automated Sizing and Training of Efficient Deep Autoencoders using Second Order Algorithms." Accessed [Date]. https://arxiv.org/pdf/2308.06221.pdf.

[3] Rane, C, Tyagi, K, and Manry, M. "Optimizing Performance of Feedforward and Convolutional Neural Networks Through Dynamic Activation Functions." Accessed [Date]. https://arxiv.org/pdf/2308.05724v1.pdf.

[4] Rajini K R Karduri, "Supercharging energy transitions through people, pockets and the planet", TheAcademic.com, July 2023

[5] B Chittoori, AJ Puppala, R Reddy, D Marshall, "Sustainable reutilization of excavated trench material" ; GeoCongress 2012: State of the Art and Practice in Geotechnical Engineering Mishra, AK, Tyagi, K, and Mishra, D. 2023. "Utilizing Super-Resolution for Enhanced Automotive Radar Object Detection." In IEEE International Conference on Image Processing (ICIP), 3563-3567.

[6] Christo Ananth, S.Mathu Muhila, N.Priyadharshini, G.Sudha, P.Venkateswari, H.Vishali, "A New Energy Efficient Routing Scheme for Data Gathering ",International Journal Of Advanced Research Trends In Engineering And Technology (IJARTET), Vol. 2, Issue 10, October 2015, pp: 1-4.

[7] Tyagi, K, Zhang, S, Zhang, Y, Kirkwood, J, Song, S, and Manukian, N. 2023. "Machine Learning Based Early Debris Detection Using Automotive Low Level Radar Data." In ICASSP 2023-2023 IEEE International Conference on Acoustics, Speech and ….

[8] Christo Ananth, S.Mathu Muhila, N.Priyadharshini, G.Sudha, P.Venkateswari, H.Vishali, "A New Energy Efficient Routing Scheme for Data Gathering ",International Journal Of Advanced Research Trends In Engineering And Technology (IJARTET), Vol. 2, Issue 10, October 2015, pp: 1-4

[9] Tyagi, K, Zhang, Y, Ahmadi, K, Zhang, S, and Manukian, N. "Machine-Learning-Based Super Resolution of Radar Data." US Patent App. 17/661,223.

[10] Rane, C, Tyagi, K, Malalur, S, Shinge, Y, and Manry, M. "Optimal Input Gain: All You Need to Supercharge a Feed-Forward Neural Network." Accessed [Date]. https://arxiv.org/pdf/2303.17732.

[11] Alcalde, C, and Tyagi, K. "Phase Space Quantization II: Statistical Ideas." In Quantum Computing: A Shift from Bits to Qubits 1085, 53–78.

[12] Alcalde, C, and Tyagi, K. "Phase Space Quantization I: Geometrical Ideas." In Quantum Computing: A Shift from Bits to Qubits 1085, 31–52.

[13] Shaw, S, Tyagi, K, and Zhang, S. "Teacher-Student Knowledge Distillation for Radar Perception on Embedded Accelerators." Accessed [Date]. https://arxiv.org/abs/2303.07586.

[14] Auddy, SS, Tyagi, K, Nguyen, S, and Manry, M. 2016. "Discriminant vector tranformations in neural network classifiers." In International Joint Conference on Neural Networks (IJCNN), 1780-1786.

[15] Cai, X, Chen, Z, Kanishka, T, Yu, K, Li, Z, and Zhu, B. "Second Order Newton's Method for Training Radial Basis Function Neural Networks."

[16] Cai, X, Tyagi, K, Manry, MT, and Chen, Z. 2014. "An efficient conjugate gradient based learning algorithm for multiple optimal learning factors of multilayer perceptron neural network." In International Joint Conference on Neural Networks (IJCNN), 1093-1099.

[17] Karduri, Rajini K R. "Cobalt in Battery Production Implications for the Mining Community." International Journal of Advanced Research In Basic Engineering Sciences and Technology.

[18] Karduri, Rajini K R. "Diversified Economies Strategies for Encouraging Varied Industries in Rural Areas." International Journal of Advanced Research In Basic Engineering Sciences and Technology.

[19] Karduri, Rajini K R. "Impacts of Fossil Fuels on Rural Communities." International Journal of Engineering Research & Technology.

[20] Karduri, Rajini K R. "Incentives for Green Technologies and Community Engagement in Decision-Making." International Journal of Advanced Research In Basic Engineering Sciences and Technology.

[21] Karduri, Rajini K R. "The Global Journey Towards a Sustainable Energy Economy." International Journal of Engineering Research & Technology.

[22] Xun Cai, MM, and Tyagi, K. "An Efficient Conjugate Gradient based Multiple Optimal Learning Factors Algorithm of Multilayer Perceptron Neural Network." In International Joint Conference on Neural Networks.

[23] Tyagi, K, Kwak, N, and Manry, M. "Optimal Conjugate Gradient algorithm for generalization of Linear Discriminant Analysis based on L1 norm." In International Conference on Pattern Recognition.

[24] Godbole, AS, Tyagi, K, and Manry, MT. 2013. "Neural decision directed segmentation of silicon defects." In The 2013 International Joint Conference on Neural Networks (IJCNN), 1-8.

[25] Tyagi, K, and Lee, K. "Applications of Deep Learning Network on Audio and Music Problems." In IEEE Computational Intelligence Society Walter Karplus Summer Research Grant

[26] Karduri, Rajini K R. "Sustainable Transportation and Electrification: Examining the Impact of Electric Vehicles (EVs) on Reducing Greenhouse Gas Emissions and Their Role in the Energy Transition." International Journal of Advanced Research In Basic Engineering Sciences and Technology.

[27] Jeong, IY, Tyagi, K, and Lee, K. "MIREX 2013: AN EFFICIENT PARADIGM FOR AUDIO TAG CLASSIFICATION USING SPARSE AUTOENCODER AND MULTI-KERNEL SVM."

[28] Tyagi, K. "Second Order Training Algorithms For Radial Basis Function Neural Networks." Department of Electrical Engineering, The University of Texas at Arlington.

[29] Cai, X, Tyagi, K, and Manry, MT. 2011. "An optimal construction and training of second order RBF network for approximation and illumination invariant image segmentation." In The 2011 International Joint Conference on Neural Networks, 3120-3126.

[30] Tyagi, K, Cai, X, and Manry, MT. 2011. "Fuzzy C-means clustering based construction and training for second order RBF network." In IEEE International Conference on Fuzzy Systems (FUZZ-IEEE 2011), 248-255.

[31] Cai, X, Tyagi, K, and Manry, MT. 2011. "Training multilayer perceptron by using optimal input normalization." In IEEE International Conference on Fuzzy Systems (FUZZ-IEEE 2011), 2771-2778.

[32] Yadav, SK, Tyagi, K, Shah, B, and Kalra, PK. 2011. "Audio signature-based condition monitoring of internal combustion engine using FFT and correlation approach." IEEE Transactions on instrumentation and measurement 60 (4): 1217-1226.

[33] RKR Karduri, "Sustainable reutilization of excavated trench material"

Civil & Environmental Engineering, UT Arlington, Texas

[34] Vekariya, RH, W Lei, A Ray, SK Saini, S Zhang, G Molnar, D Barlow, et al. "Synthesis and Structure–Activity Relationships of 5′-Aryl-14-alkoxypyridomorphinans: Identification of a μ Opioid Receptor Agonist/δ Opioid Receptor Antagonist Ligand." Journal of Medicinal Chemistry 63, no. 14 (2020): 7663-7694.

[35] Ray, A, S Mukherjee, J Das, MK Bhandari, H Du, M Yousufuddin, et al. "Preparation and Diels–Alder Reactions of 1′-heterosubstituted vinylimidazoles." Tetrahedron Letters 56, no. 23 (2015): 3518-3522.

[36] Ray, A, M Yousufuddin, D Gout, CJ Lovely. "Intramolecular Diels–Alder Reaction of a Silyl-Substituted Vinylimidazole en Route to the Fully Substituted Cyclopentane Core of Oroidin Dimers." Organic Letters 20, no. 18 (2018): 5964-5968.

[37] Ray, A, S Mukherjee, J Das, M Bhandari, A Herath, M Yousufuddin, et al. "HETEROSUBSTITUTED 4-VINYLIMIDAZOLES: PREPARATION AND DIELS-ALDER REACTIONS (Dedicated to Professor Tohru Fukuyama on the occasion of his 70th birthday)." Heterocycles: An International Journal for Reviews and Communications (2019).

[38] Ray, A. "APPLICATION OF NOVEL HETEROSUBSTITUTED VINYLIMIDAZOLES: AN APPROACH EN ROUTE TO THE TOTAL SYNTHESIS OF AXINELLAMINE A." (2016).

[39] Ray, A, C Lovely. "Synthesis and Diels-Alder reactions of 1'-heterosubstituted 4-vinylimidazoles: A novel approach en route to the total synthesis of dimeric oroidin alkaloids." Abstracts of Papers of the American Chemical Society 250 (2015).

[40] Ray, A, S Mukherjee, CJ Lovely. "Preparation and study of intermolecular Diels-Alder reaction of substituted 4-vinylimidazole derivatives." Abstracts of Papers of the American Chemical Society 247.

[41] Obaid, M., Udden, S. M. N., Deb, P., Shihabeddin, N., Zaki, M. H., & Mandal, S. S. "LncRNA HOTAIR regulates lipopolysaccharide-induced cytokine expression and inflammatory response in macrophages." Scientific Reports 8, no. 1 (2018): 15670.

[42] Deb, P., Bhan, A., Hussain, I., Ansari, K. I., Bobzean, S. A., Pandita, T. K., ... & Perrotti, L. I. "Endocrine disrupting chemical, bisphenol-A, induces breast cancer associated gene HOXB9 expression in vitro and in vivo." Gene 590, no. 2 (2016): 234-243.

[43] Hussain, I., Bhan, A., Ansari, K. I., Deb, P., Bobzean, S. A., Perrotti, L. I., & Mandal, S. S. "Bisphenol-A induces expression of HOXC6, an estrogen-regulated homeobox-containing gene associated with breast cancer." Biochimica et Biophysica Acta (BBA)-Gene Regulatory Mechanisms 1849, no. 6 (2015): 697-708.

[44] Bhan, A., Deb, P., Shihabeddin, N., Ansari, K. I., Brotto, M., & Mandal, S. S. "Histone methylase MLL1 coordinates with HIF and regulates lncRNA HOTAIR expression under hypoxia." Gene 629 (2017): 16-28.

[45] Hussain, I., Deb, P., Chini, A., Obaid, M., Bhan, A., Ansari, K. I., ... & Mishra, B. P. "HOXA5 expression is elevated in breast cancer and is transcriptionally regulated by estradiol." Frontiers in Genetics 11 (2020): 592436.

[46] Bhan, A., Deb, P., & Mandal, S. S. "Epigenetic code: histone modification, gene regulation, and chromatin dynamics." In Gene regulation, epigenetics and hormone signaling (2017): 29-58.

[47] Deb, P., & Mandal, S. S. "Endocrine disruptors: mechanism of action and impacts on health and environment." In Gene regulation, epigenetics and hormone signaling (2017): 607-638.

[48] Deb, P. "Epigenetic Mechanism of Regulation of Hox Genes and Neurotransmitters Via Hormones and LNCRNA." The University of Texas at Arlington (2017).

[49] Deb, P., Bhan, A., & Mandal, S. "Mechanism of transcriptional regulation of EZH2 (H3K27 methyltransferase) by 17 beta-estradiol and estrogenic endocrine disrupting chemicals." Abstracts of Papers of the American Chemical Society 247 (2014): 120.

[50] Bhan, A., Deb, P., Soleimani, M., & Mandal, S. S. "The Short and Medium Stories of Noncoding RNAs: microRNA and siRNA." In Gene Regulation, Epigenetics and Hormone Signaling (2017): 137-168.