# A Detailed Review on Sustainable Engineering Methods Integrated with Waste Management Practices

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**Abstract.** Environmental engineering is a broad field that considers the complex interactions between natural issues and human action to make long-term arrangements and provide solutions. Natural designing uses many principles from the field of chemistry science, material technology, and other research to analyse and carry out strategies for resource conservation, protecting the environment, and the minimization of contaminated particles and polluting substances. The focus of the paper is on the sustainable and waste management practices that can reduce the undesirable effects such as carbon prints on the environment. the framework has been designed to attract more and more industries and management to achieve the sustainable growth of the sector. The key objectives of remediation activities are to safeguard public health, repair harmed ecosystems, and encourage the long-term, sustainable use of contaminated land or that area. Environmental engineering will continue to be essential in helping to shape a more sustainable relationship between humans and the natural world as society faces constantly shifting ecological issues and all the challenges related to the environment.

**Keyword-:** Environmental engineering, Sustainable future, Ecosystems, Wastewater treatment, Solid waste management, forest area.

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# 1 Introduction

When we go through the environmental engineering it plays a vital role in maintaining the quality of the environment and advancing societal well-being, especially in light of growing concerns about pollution, resource depletion, and climate change [1]. So, the study offers a discerning assessment of environmental engineering, by covering its crucial concepts, innovative approaches, and critical parts in decreasing the destruction in the environment. This sort of strategy includes a wide run of disciplines, such as squander treatment, contamination control, natural remediation, and administration of water quality [2]. These engineers make comprehensive arrangements for troublesome natural issues by melding thoughts from a few logical and designing areas, including chemistry, science, material science, and frameworks examination conjointly assessments [3]. In environmental engineering innovation and development have progressed essentially in later a long time, coming about through the improvement of inventive arrangements for natural issues that cause harmful effects to us [4]. These experts are driving the way in advancing positive shifts and natural supportability, from the creation of advanced amenities, resources, and water treatment frameworks to the sending of renewable energy sources [5]. The main reason for this paper is to look at imperative features of environmental engineering, such as its chronicled advancement, new approaches, and creating patterns that are in today's time [2]. Over the past few decades, the field has made critical developments, driven by laws expecting to diminish a few of the foremost genuine sorts of natural harm and open estimation in support of protecting and keeping secure human wellbeing and common assets. But the issues of the future cannot be solved by using the methods of the past and that is the challenge to take technology to newer heights to meet the present needs. That is why to serve the interests of people and the environment, these engineering professionals must build on their distinctive strengths, inspire and implement visionary solutions, and continue to evolve as humanity faces a growing number of diversified and new bigger challenges [6]. Urban areas are expanding rapidly, placing immense pressure on natural resources and ecosystems. Mechanical workouts increment in contamination and asset utilization, so inventive arrangements for workable generation and squander administration are required to reduce the garbage collection [7]. Complex natural issues have been exacerbated by globalization and calls for facilitated endeavours at the nearby, national, and worldwide levels [8]. In arrange to realize maintainability, common engineers ought to adjust to these moving streams by seizing curious openings, using state-of-the-art improvements, and advancing procedures that advance flexibility and characteristic stewardship [9]. This engineering field can play a vital part in the planet's future by working together to create designs and collaborate over divisions [10].

# 2 Environmental Engineering for the 21$^{st}$ Century

Today's squeezing worldwide issues require the application of natural designing in arrange to be unravelled and a feasible future for both the present and long-term eras to come. In light of the ever-growing concerns around climate-changes, contamination, resource exhaustion, and environmental pollution, these proficient engineers are driving the way in creating novel procedures to protect the environment and advance human wellbeing. Looking at the major concerns, rising ways, and openings for long-term prosperity development that are feasible, this paper investigates the advancement of natural designing within the twenty-first century. The twenty-first century presents several novels and phenomenal deterrents and challenges for environmental engineers, which require inventive considering and participation in arrange to effectively explore because it gives a critical output about the field. Climate change is one of the foremost squeezing issues to address and ensure environments, as proven by the way

that extraordinary climate, rising ocean levels, and rising worldwide temperatures are undermining environments and communities around the world [11]. Inside this framework, discussing pollution such as water, and soil pollution that continues to compound natural conditions and imperil open well-being [12]. There are some challenges like exhaustion of assets, living space annihilation, and biodiversity misfortune that are major dangers to the ecosystem's maintainability and robustness [13]. With all these obstacles come in underway, the twenty-first century has seen incredible strides in the environmental engineering field, which is propelled by interdisciplinary cooperation, technological innovation, and a heightened consciousness of sustainability and long-term viability. The major power Hydroelectric, solar, and wind energy are examples of renewable energy technologies that present viable ways to reduce or lower greenhouse gas emissions and wean ourselves off of fossil fuels or natural resources [14]. The continuous tracking and monitoring of environmental parameters is made possible by advanced technology and data analytics, which promotes more effective resource management and pollution control which could be helpful [15].

In contrast to conventional remediation techniques, biological remediation processes, and botanical remediation methods use the natural processes of microorganisms and plants to clean up contaminated sites at a lower cost and with more long-term sustainability with longer outcomes [16]. To create a more resilient and sustainable economy, circular economy principles support reducing waste production, optimizing resource efficiency, and encouraging the reuse and recycling of all waste materials [17]. The field of environmental engineering has enormous potential to promote sustainable development and bring about positive change in the 21st century, regardless of the obstacles and opportunities it faces. All the approaches to integrated water resource management balance conflicting demands from industry, urbanization, and agriculture while promoting the sustainable use and conservation of water resources.

The fundamental impacts of urban heat islands have been lowered, storm water runoff is decreased, and urban biodiversity is increased with the use of green infrastructure solutions that include built aquatic ecosystems, permeable pavements, and green roofs that are sustainable [18]. In this field, public engagement and environmental educational programs enable people to take up sustainable habits, support environmental conservation, and take part in decision-making processes that educate them [19]. So international partnerships and collaborations promote global cooperation to address worldwide environmental issues by facilitating knowledge sharing, capacity building, and technology transfer which is innovative [20-24]. This field is becoming more and more important as we negotiate the challenges of the 21st century to advance equity, resilience, and sustainability to get a better future. Due to the adoption of innovation, cooperation, and care, environmental engineers can effectively tackle contemporary issues and construct a more sustainable and prosperous future that benefits all humans as well as the ecosystem [25]. Table 1 evaluates the performance of forestry system by considering ecological and economic benefits while also addressing carbon emissions [26]. For the inputs of land, capital, labor, energy and their average, minimum and maximum values have desired and undesired outputs with the mean value of desired output in carbon sink is ~16326 MT and in undesired output carbon emission the average value is ~470 MT. Fig 1 shows the process for environmental engineering in the 21st century [27-30].

**Table 1.** Statistical analysis of input-output variables on Environment [31]

| Variable | Definition | Mean | Min | Max |
|---|---|---|---|---|
| Inputs (forestry system) | | | | |
| Land | Forest land area (hectares) | 931.599 | 2.250 | 4499.170 |
| Capital | Forestry fixed-asset investment (in $) | 12.002 | 0.009 | 469.432 |
| Labor | Number of employees in forestry system | 44,912.677 | 704.000 | 470,317.000 |
| Energy | Forestry energy investment (in $) | 15.122 | 0.028 | 438.191 |
| Desired output (carbon sinks) | | | | |
| Economic benefits | Forestry output value (in $) | 969.187 | 2.038 | 8167.577 |
| Ecological benefits | Forestry carbon sink (metric tons) | 16,326.196 | 14.707 | 87,281.959 |
| Undesired output (carbon emissions) | | | | |
| Carbon emissions | Forestry carbon emissions (metric tons) | 470.182 | 0.406 | 3256.067 |

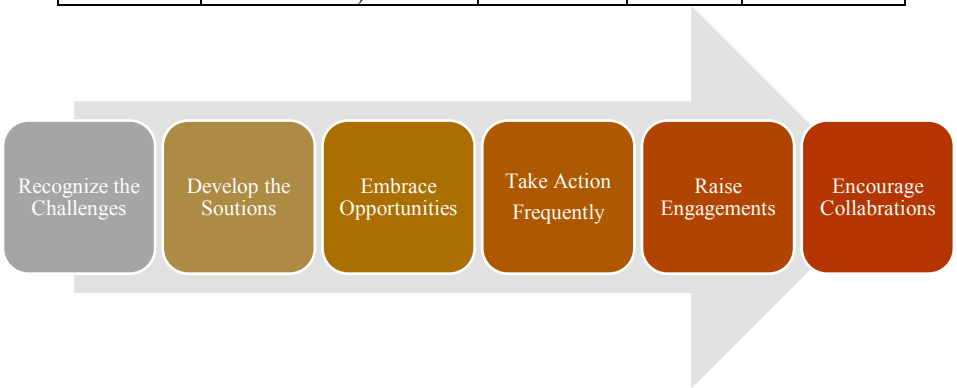


**Fig. 1.** Process for Environmental Engineering in the 21st Century for more industrial collaborations

## 3 Challenges and Solutions

The field of environmental engineering faces multiple challenges such as pollution and climate change, as well as habitat destruction and rapid resource depletion [32]. Due to this it minimizes the effects of these issues and advances sustainability, coordinated efforts, and creative solutions are needed which is vital [33-35]. So, this paper looks at the main issues that environmental engineers are currently facing and the wide range of solutions that are being developed and proposed to deal with them to resolve the issues. Nowadays climate change and its extensive effects on ecosystems, infrastructure, and human well-being, is one of the most difficult problems faced by environmental engineers in this profession [36]. The world's most vulnerable communities, ecosystems, and vital infrastructure are at serious risk from rising global temperatures, changing precipitation patterns, and an increase in the frequency of extreme weather events that are too hazardous [37]. One of the concerns about pollution is a result of industrial operations, farming methods, and urbanization, which causes environmental damage and ecosystem collapse badly [38]. At this time sustainability and

ecosystem resilience face significant challenges due to the depletion of natural resources, such as freshwater, forests, and minerals contents in the earth's surface [39-41]. Fig 2 contains some points on challenges. The sustainable engineering for the environment faces these obstacles and provides a multitude of inventive solutions to crucial environmental problems in Fig. 3. At the top clean and sustainable fossil fuel substitutes, like solar, wind, and hydroelectric power, lower greenhouse gas emissions [42].

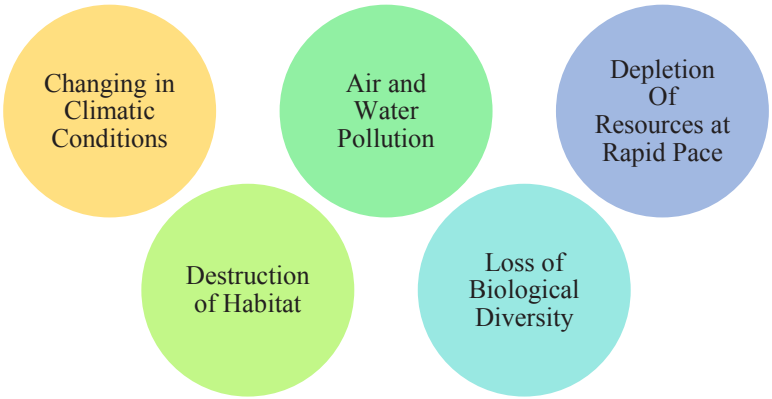


**Fig. 2.** Challenges of Sustainable Environment


**Fig. 3.** Solutions of Sustainable Environment

## 4 Global Developments and Steps towards sustainable Engineering

Several new developments in the field of environmental engineering are changing the sector's landscape and directing future study and application to the new road [43]. These numerous factors, such as shifting societal priorities, environmental shifts, and technological advancements, are contributing to these trends and evolving generously. Climate resilience engineering is one of the major new trends in environmental engineering due to its technology

[44]. So the infrastructure and systems need to be designed to be able to withstand and adapt to changing climate conditions, as the frequency and intensity of extreme weather events like hurricanes, floods, wildfires, and many other calamities increase rapidly [45]. The procedure to approach incorporating climate change considerations into the planning, development, and maintenance of infrastructure projects from transportation networks and buildings to water supply systems and coastal defences all come under climate resilience technological advances [46]. The growth of increasing the adaptability of communities and vital infrastructure to climate-related hazards involves requiring policies in place like green infrastructure, flood-proofing methods, and resilient resources for building or construction sites [47-50].

Another significant and very important trend now influencing environmental engineering sustainable urbanization. With over half of the world's population now living in cities or in urban areas, the need to create environmentally sustainable and socially just urban environments is becoming more and more pushing the limits [51]. Just because sustainable urbanization involves arranging, and planning cities and metropolitan regions to minimize their negative effects on the environment, encourage and promote resource efficiency, and improve the standard of living for the local population. By cutting carbon emissions in urban areas or cities it implements energy-efficient construction designs by promoting sustainable options [52-55]. These environmental engineers can address and resolve the environmental issues brought on by rapid urbanization and promote safer, more durable liveable cities by implementing sustainable urbanization principles to the environment. These engineers are also adopting the concepts of the circular economy [56]. The economic model which is known as "circular economy" seeks to reduce waste production, increase resource efficiency, and encourage material reuse and recycling of all the waste and treat it [57]. An emerging area of focus is sustainable water management, especially in developing nations because of its impact. It is still exceptionally challenging to ensure and provide clean water access while reducing environmental impact, so comprehensive and particular to the situation solutions are required to be found [58]. A growing number of sustainable and environment-friendly building and construction materials are being developed as a result of worries about shortages of resources and environmental damage or degradation [59]. Table 3 includes the data of European Union (EU) on waste management circular economy, along with descriptive statistics. Taking different years was possible due to the assumption that there were no radical changes in the economies of individual countries in recent years [40].

The objective of improvements to materials science is to lower the carbon footprint of building projects and to promote and move forward with the ideas of the circular economy [60]. In the construction sector, applying circular economy principles into operation promotes resource resilience, efficiency as well as productivity in addition to waste reduction and reuse and recycling the waste. Environmental engineers are increasingly exploring innovative approaches to waste management, product design, and resource recovery to transition toward a more circular economy [61]. To make the shift towards a more circular economy, engineers are constantly investigating novel techniques for resource recovery, waste management, and product design. Reducing waste materials and increasing the value of resources, involves implementing strategies like recycling waste into energy technologies, continuously recycling systems, and sustainable product design practices into action. These professional engineers can adopt the circular economy fundamentals and can contribute to more sustainable resource management by reducing human actions. Table 2 describes the emerging trends and its key point.

**Table 2.** Emerging trends and Its Components

| Emerging Trend | Key Aspects/Components | References |
|---|---|---|
| Climate Resilience Engineering | Including climate change concerns in the planning, building, and maintenance of infrastructure<br>Application of resilient building materials and green infrastructure<br>Actions to make vital infrastructure and communities more resilient to climate-related risks | [29], [30] |
| Sustainable Urbanization | Minimising the effects on the environment when designing cities and urban areas<br>Encouragement of resource economy<br>Combining environmentally friendly areas with eco-friendly transportation choices<br>Putting energy-efficient building designs into practice | [31-35] |
| Circular Economy Principles | Reduction of waste production<br>Maximising the effectiveness of available resources<br>Encouragement of material recycling and reuse<br>Putting in place closed-loop recycling systems and waste-to-energy technologies<br>Adopting sustainable product design principles | [36-38] |

**Table 3.** European Union Circular Economy Monitoring framework data table on waste management

| Indicator | Original EU Indicator and Unit | Indicator Used | Abbrev | Average | Max | Min | Std Dev |
|---|---|---|---|---|---|---|---|
| Recycling rates | Recycling rate of municipal waste (percentage) | Recycling rate of municipal waste (percentage) 2019 | W1 | 39.500 | 66.700 | 8.900 | 14.547 |
| | Recycling rate of all waste excluding major mineral waste (percentage) | Recycling rate of all waste excluding major mineral waste (percentage) 2018 | W2 | 50.630 | 82.000 | 10.000 | 17.502 |
| Recycling/recovery for specific waste streams | Recycling rate of packaging waste by type of packaging | Recycling rate of overall packagin | W3 | 64.070 | 85.300 | 35.700 | 9.059 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | g (percentage) 2018 | | | | | |
| | Recycling rate of packaging waste by type of packaging | Recycling rate of plastic packaging (percentage) 2018 | W4 | 41.104 | 69.300 | 11.100 | 12.110 |
| | Recycling rate of packaging waste by type of packaging | Recycling rate of wooden packaging (percentage) 2018 | W5 | 36.193 | 90.600 | 0.000 | 21.802 |
| | Recycling/recovery for specific waste streams | Recycling rate of e-waste (percentage) 2018 | W6 | 44.578 | 83.400 | 20.800 | 12.751 |
| | Recycling/recovery for specific waste streams | Recycling of biowaste (kg per capita) 2019 | W7 | 69.556 | 189.000 | 0.000 | 51.458 |
| | Recycling/recovery for specific waste streams | Recovery rate of construction and demolition waste (percentage) 2018 | W8 | 86.296 | 100.000 | 24.000 | 17.518 |

## 5 Conclusion

When considering recent developments in the discipline, a few key features become apparent where environmental engineering is at the forefront of solving the world's most important problems and guiding humanity toward a sustainable future to mankind. The paper concluded the following key aspects to be covered when designing any engineering project:

- Promotion of accessible urban communities through the integration of green spaces in biodiversity, energy-efficient design implementation, execution, and sustainable transportation representation.
- The study found that the impact of the undesirable factors such as carbon prints can be reduced by changing the input variables such as forest area and its management that will enhance the ecological and environmental benefits.

- The professionals in the field have a big role in looking forward to and adopting circular economy practices such as recycling systems, generating energy from waste and making sustainable design for products.
- The total practices are disrupted by increased digitalization and data analytics, such as real-time monitoring, forecasting, and data-driven decision-making in environmental engineering. By using various methods and devices such as sensors, auto remote sensing, and AI engineers can improve their efforts in monitoring and addressing.

## References

1. Vesilind, P. A., Morgan, S. M., & Heine, L. G. Introduction to Environmental Engineering. Cengage Learning, (2018).
2. Zhang, T. C., Lo, I. M. C., & Zhang, D. Environmental Engineering Science. CRC Press, (2015).
3. Rao, P. S. Environmental Pollution Control Engineering. Wiley, (2014).
4. DiBiasio, D. L. Environmental Engineering: Fundamentals, Sustainability, Design. Wiley, (2020).
5. Naik, R., Prashantha, S. C., & Nagabhushana, H. (2017). Effect of Li+ codoping on structural and luminescent properties of Mg2SiO4: RE3+ (RE= Eu, Tb) nanophosphors for displays and eccrine latent fingerprint detection. Optical Materials, 72, 295-304.
6. Bhadauria, Alok, Shipra Bajpai, Ashutosh Tiwari, Shiva Kant Mishra, Ambreen Nisar, Shruti Dubey, Nishant Chavan, Anup K. Keshri, and Kantesh Balani. "Bimodal microstructure toughens plasma sprayed Al2O3-8YSZ-CNT coatings." Ceramics International 49, no. 8 (2023): 12348-12359.
7. National Academies of Sciences, Division on Engineering, Physical Sciences, Division on Earth, Life Studies, Water Science, Technology Board et al. Environmental engineering for the 21st century: Addressing grand challenges. National Academies Press, (2019).
8. Akshatha, S., Sreenivasa, S., Parashuram, L., Kumar, V. U., Sharma, S. C., Nagabhushana, H., ... & Maiyalagan, T. (2019). Synergistic effect of hybrid Ce3+/Ce4+ doped Bi2O3 nano-sphere photocatalyst for enhanced photocatalytic degradation of alizarin red S dye and its NUV excited photoluminescence studies. Journal of Environmental Chemical Engineering, 7(3), 103053.
9. Appannagari, Ramamohana Reddy. "Environmental pollution causes and consequences: a study." North Asian International Research Journal of Social Science & Humanities 3, 8 (2017): 151-161.
10. Bhadauria, Alok, Lavish Kumar Singh, Atul Ramesh Ballal, and R. Vijay. "Effect of Yttria dispersion on creep properties of pure iron." Transactions of the Indian Institute of Metals 69 (2016): 253-259.
11. Naik, R., Prashantha, S. C., Nagabhushana, H., Sharma, S. C., Nagaswarupa, H. P., Anantharaju, K. S., ... & Girish, K. M. (2015). A single phase, red emissive Mg2SiO4: Sm3+ nanophosphor prepared via rapid propellant combustion route. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 140, 516-523.
12. Bibri, Simon Elias, John Krogstie, Amin Kaboli, and Alexandre Alahi. "Smarter eco-cities and their leading-edge artificial intelligence of things solutions for environmental sustainability: A comprehensive systematic review." Environmental Science and Ecotechnology 19 (2024): 100330.
13. Mihelcic, James R., Colleen C. Naughton, Matthew E. Verbyla, Qiong Zhang, Ryan W. Schweitzer, Stewart M. Oakley, E. Christian Wells, and Linda M. Whiteford. "The grandest challenge of all: The role of environmental engineering to achieve

sustainability in the world's developing regions." Environmental Engineering Science 34, 1 (2017): 16-41.
14. Ramakrishna, G., Naik, R., Nagabhushana, H., Basavaraj, R. B., Prashantha, S. C., Sharma, S. C., & Anantharaju, K. S. (2016). White light emission and energy transfer (Dy3+→ Eu3+) in combustion synthesized YSO: Dy3+, Eu3+ nanophosphors. Optik, 127(5), 2939-2945.
15. Jisha, P. K., Naik, R., Prashantha, S. C., Nagabhushana, H., Sharma, S. C., Nagaswarupa, H. P., ... & Premkumar, H. B. (2015). Facile combustion synthesized orthorhombic GdAlO3: Eu3+ nanophosphors: Structural and photoluminescence properties for WLEDs. Journal of Luminescence, 163, 47-54.
16. Bhukya, M. N., Kota, V. R., & Depuru, S. R. (2019). A simple, efficient, and novel standalone photovoltaic inverter configuration with reduced harmonic distortion. IEEE access, 7, 43831-43845.
17. Naresh, M., & Munaswamy, P. (2019). Smart agriculture system using IoT technology. International journal of recent technology and engineering, 7(5), 98-102.
18. IPCC. Special Report on Global Warming of 1.5°C. Intergovernmental Panel on Climate Change, 2018.
19. WHO. Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease. World Health Organization, 2018.
20. Ramkumar, M., Babu, C. G., Kumar, K. V., Hepsiba, D., Manjunathan, A., & Kumar, R. S. (2021, March). ECG cardiac arrhythmias classification using DWT, ICA and MLP neural networks. In Journal of Physics: Conference Series (Vol. 1831, No. 1, p. 012015). IOP Publishing
21. IPBES. Global Assessment Report on Biodiversity and Ecosystem Services. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019.
22. Karuppusamy, L., Ravi, J., Dabbu, M., & Lakshmanan, S. (2022). Chronological salp swarm algorithm based deep belief network for intrusion detection in cloud using fuzzy entropy. International Journal of Numerical Modelling: Electronic Networks, Devices and Fields, 35(1), e2948.
23. IEA. Renewables 2020: Analysis and Forecast to 2025. International Energy Agency, 2020.
24. Zhang, K., et al. "Smart Environmental Monitoring Systems: A Review." IEEE Access, 8, (2020): 183893-183908.
25. Singh, O. V., et al. "Bioremediation: Environmental Clean-Up through Environmentally Friendly Technologies." Journal of Biotechnology, 3(1), (2016):1-8.
26. Bhadauria, Alok, Lavish Kumar Singh, and Tapas Laha. "Nanoindentation and nanoscratch properties of graphene nanoplatelets reinforced spark plasma sintered aluminium-based nanocomposite." Advances in Materials and Processing Technologies 5, no. 2 (2019): 295-302.
27. Ramprasad, P., Basavapoornima, C., Depuru, S. R., & Jayasankar, C. K. (2022). Spectral investigations of Nd3+: Ba (PO3) 2+ La2O3 glasses for infrared laser gain media applications. Optical Materials, 129, 112482.
28. Goud, J. S., Srilatha, P., Kumar, R. V., Kumar, K. T., Khan, U., Raizah, Z., ... & Galal, A. M. (2022). Role of ternary hybrid nanofluid in the thermal distribution of a dovetail fin with the internal generation of heat. Case Studies in Thermal Engineering, 35, 102113.
29. European Commission. Green Infrastructure (GI) — Enhancing Europe's Natural Capital. European Commission, 2015.
30. UNESCO. Education for Sustainable Development Goals: Learning Objectives. United Nations Educational, Scientific and Cultural Organization, (2017).

31. UNEP. Global Environment Outlook 6: Regional Assessments. United Nations Environment Programme, (2016).
32. NOAA. State of the Climate: Global Climate Report. National Oceanic and Atmospheric Administration, (2020).
33. United Nations Environment Programme (UNEP). Global Environment Outlook - GEO-6: Healthy Planet, Healthy People, (2019).
34. World Wildlife Fund (WWF). Living Planet Report 2020: Bending the Curve of Biodiversity Loss, (2020).
35. Dandekar, Tushar Ramdas, Rajesh Kisni Khatirkar, Aman Gupta, Nitish Bibhanshu, Alok Bhadauria, and Satyam Suwas. "Strain rate sensitivity behaviour of Fe–21Cr-1.5 Ni–5Mn alloy and its constitutive modelling." Materials Chemistry and Physics 271 (2021): 124948.
36. Suji Prasad, S. J., Thangatamilan, M., Suresh, M., Panchal, H., Rajan, C. A., Sagana, C., ... & Sadasivuni, K. K. (2022). An efficient LoRa-based smart agriculture management and monitoring system using wireless sensor networks. International Journal of Ambient Energy, 43(1), 5447-5450.
37. Akshatha, S., Sreenivasa, S., Parashuram, L., Alharthi, F. A., & Rao, T. M. C. (2021). Microwave assisted green synthesis of p-type Co3O4@ Mesoporous carbon spheres for simultaneous degradation of dyes and photocatalytic hydrogen evolution reaction. Materials Science in Semiconductor Processing, 121, 105432.
38. Yue, L., Jayapal, M., Cheng, X., Zhang, T., Chen, J., Ma, X., ... & Zhang, W. (2020). Highly dispersed ultra-small nano Sn-SnSb nanoparticles anchored on N-doped graphene sheets as high performance anode for sodium ion batteries. Applied Surface Science, 512, 145686.
39. Environmental Protection Agency (EPA). Air Pollution Control Technology Fact Sheet, (2020).
40. World Health Organization (WHO). Water Treatment: Assessing the Environmental Burden of Disease at National and Local Levels,(2017).
41. Convention on Biological Diversity (CBD). Global Biodiversity Outlook 4, (2018).
42. Rosenzweig, C., & Solecki, W. D. Climate change adaptation in New York City: Building a risk management response. Annals of the New York Academy of Sciences, 1336(1), (2018): 56-66.
43. United Nations. “World Urbanization Prospects: The 2018 Revision.” Department of Economic and Social Affairs, Population Division, (2019).
44. Ellen MacArthur Foundation. “Towards the Circular Economy: Accelerating the Scale-Up across Global Supply Chains, (2017).
45. Lee, J., & Kim, T. Emerging trends and challenges in environmental engineering: Opportunities and implications for sustainable development. Sustainability, 12(8), (2020): 3393.
46. United Nations Environment Programme. Nature-based Solutions: From Paris to Kunming, (2020).
47. Cosgrove, William J., and Daniel P. Loucks. "Water management: Current and future challenges and research directions." Water Resources Research 51, no. 6 (2015): 4823-4839.
48. Omisore, Akinlolu G. "Attaining Sustainable Development Goals in sub-Saharan Africa; The need to address environmental challenges." Environmental development 25 (2018): 138-145.
49. Long, Hualou, Shuangshuang Tu, Dazhuan Ge, Tingting Li, and Yansui Liu. "The allocation and management of critical resources in rural China under restructuring: Problems and prospects." Journal of Rural Studies 47 (2016): 392-412.

50. Patil, S., & Anandhi, R. J. (2020). Diversity based self-adaptive clusters using PSO clustering for crime data. International Journal of Information Technology, 12(2), 319-327.
51. Indira, D. N. V. S. L. S., Ganiya, R. K., Ashok Babu, P., Xavier, A., Kavisankar, L., Hemalatha, S., ... & Yeshitla, A. (2022). Improved artificial neural network with state order dataset estimation for brain cancer cell diagnosis. BioMed Research International, 2022.
52. Jaidass, N., Moorthi, C. K., Babu, A. M., & Babu, M. R. (2018). Luminescence properties of Dy3+ doped lithium zinc borosilicate glasses for photonic applications. Heliyon, 4(3).
53. Norouzi, Masoud, Marta Chàfer, Luisa F. Cabeza, Laureano Jiménez, and Dieter Boer. "Circular economy in the building and construction sector: A scientific evolution analysis." Journal of Building Engineering 44 (2021): 102704.
54. Rahla, Kamel Mohamed, Ricardo Mateus, and Luís Bragança. "Implementing circular economy strategies in buildings—from theory to practice." Applied System Innovation 4, 2 (2021): 26.
55. Lakshmi, L., Reddy, M. P., Santhaiah, C., & Reddy, U. J. (2021). Smart phishing detection in web pages using supervised deep learning classification and optimization technique ADAM. Wireless Personal Communications, 118(4), 3549-3564.
56. Spandana, K., & Rao, V. S. (2018). Internet of Things (Iot) Based smart water quality monitoring system. International Journal of Engineering and Technology (UAE), 7(3), 259-262.
57. Kumar, K. U., Babu, P., Basavapoornima, C., Praveena, R., Rani, D. S., & Jayasankar, C. K. (2022). Spectroscopic properties of Nd3+-doped boro-bismuth glasses for laser applications. Physica B: Condensed Matter, 646, 414327.
58. European Environment Agency. Circular economy in Europe: insights on progress and potential, (2019).
59. Wang, Fengting, Hao Wang, Cong Liu, Lichun Xiong, and Zhiquan Qian. "The effect of green urbanization on forestry green total factor productivity in China: analysis from a carbon neutral perspective." Land 11, no. 11 (2022): 1900.
60. Nazarko, Joanicjusz, Ewa Chodakowska, and Łukasz Nazarko. "Evaluating the transition of the european union member states towards a circular economy." Energies 15, no. 11 (2022): 3924.