QUATERLY NEWSLETTER

ECOTECH TALKS

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-A collective endeavour for sustainability and change!
(Under the aegis of H.M.E-Waste Management)

Let's be a Green Change Maker!
Talk II Share II Act

INSIDE THE
NEWSLETTER

THE EDITOR'S NOTE

AI & Automation in E-Waste Recycling: A Major Leap Towards Circular Economy

Dear Readers,

Greetings!

The global surge in Electronic and Electrical Equipment (EEE) consumption has led to a parallel rise in E-waste (WEEE) – which represents a unique yet complicated waste stream, with environmental, economic and social implications! Infact, the traditional recycling methods struggle to keep pace with the complexity of modern gadgets/devices having sophisticated built and design, thereby making these traditional methods less efficient and not sustainable. In this context, the Advanced Recycling Technologies, including AI and Automation in e-waste recycling, have got immense potential to revolutionize the traditional methods by enhancing efficiency, precision and scalability, thereby taking a major leap towards sustainable e-waste management and circular economy.

So, the July Edition (2025) of EcoTech Talks presents perspectives around pertinent topics like Advanced Recycling Technologies, including AI and Automation in WEEE Recycling Sector, to update the concerned industry stakeholders on these latest and transformational innovative trends.

Have a happy reading!

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GREEN CONTRIBUTORS AND THEIR EXPERT OPINION

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Advancement in Recycling Technologies of E-Waste

The exponential growth of electronic devices in the 21st century has created an unprecedented challenge for waste management systems worldwide. Electronic waste, commonly referred to as e-waste, represents one of the fastest-growing waste streams globally, with an estimated 54 million metric tons generated in 2019 alone. This staggering figure is projected to reach 74.7 million metric tons by 2030, highlighting the urgent need for innovative and efficient recycling technologies. The complexity of electronic devices, containing a mixture of valuable metals, hazardous substances, and various polymers, demands sophisticated approaches to recovery and processing that go far beyond traditional waste management methods. The evolution of e-waste recycling technologies has been driven by multiple factors, including environmental regulations, resource scarcity, economic incentives, and growing awareness of the environmental and health impacts associated with improper disposal of electronic devices.

Automated Disassembly and Sorting Technologies

The foundation of modern e-waste recycling lies in sophisticated automated disassembly systems that have revolutionized the initial processing stages. These systems employ advanced robotics, AI, and machine learning algorithms to identify, categorize, and dismantle electronic devices with precision that far exceeds human capabilities. Robotic disassembly systems utilize computer vision technology to recognize different types of electronic components, assess their condition, and determine the optimal disassembly sequence to maximize material recovery while minimizing damage to valuable components.

The adaptive robotic systems can handle the vast diversity of electronic devices entering recycling facilities as are equipped with multiple tool heads and can switch between different disassembly techniques depending on the device type, age, and construction method.

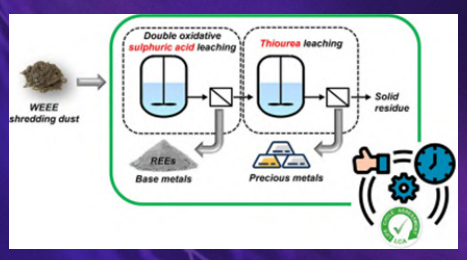
The sorting phase has been equally transformed through the implementation of advanced sensor technologies. Multi-spectral imaging systems can identify materials based on their optical properties, while X-ray fluorescence spectroscopy enables precise identification of metal compositions even in complex alloys.

Artificial Intelligence and Machine Learning Integration

The integration of artificial intelligence and machine learning technologies has transformed e-waste recycling from a largely manual and intuitive process into a data-driven, optimized operation. Advanced AI systems can analyse vast amounts of data from sensors, cameras, and other monitoring equipment to make real-time decisions about processing parameters, material flows, and equipment operation.

Predictive maintenance systems powered by machine learning algorithms monitor equipment performance and predict potential failures before they occur which significantly reduces downtime and maintenance costs while ensuring consistent processing quality. Computer vision systems enhanced with deep learning algorithms have achieved remarkable accuracy in identifying and classifying electronic components and materials. These systems can distinguish between different types of plastics, identify specific metal alloys and even assess the condition and potential value of individual components.

Hydrometallurgical Processing Innovations



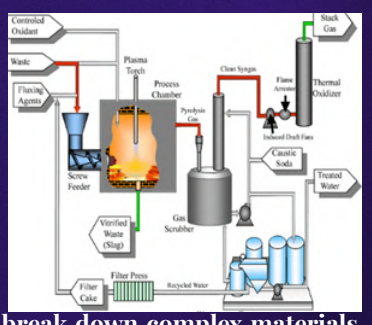
The recovery of precious and rare earth metals from e-waste has been revolutionized through advances in hydrometallurgical processing techniques.

Modern hydrometallurgical processes utilize carefully designed chemical solutions and controlled reaction conditions to selectively dissolve and recover specific metals with high purity and minimal environmental impact.

Bioleaching represents one of the most promising developments in this field, utilizing specially selected microorganisms to extract metals from electronic components. These biological processes operate under mild conditions, reducing energy consumption and eliminating the need for harsh chemicals. Certain bacteria and fungi have been identified that can efficiently extract gold, silver, copper, and other valuable metals from printed circuit boards and other electronic components.

Ionic liquid extraction has emerged as another groundbreaking technology for metal recovery from e-waste. These designer solvents can be tailored to selectively extract specific metals while leaving others untouched, enabling highly efficient separation processes. The ability to recover and reuse ionic liquids makes this technology both economically viable and environmentally sustainable.

Plasma and Thermal Processing Technologies

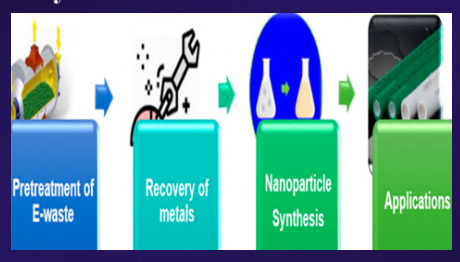


High-temperature processing technologies have undergone significant evolution to address the challenges of e-waste recycling while minimizing environmental impact. Plasma arc technology represents a cutting-edge approach that utilizes extremely high temperatures generated by electrical arcs to break down complex materials into their constituent elements. The development of controlled atmosphere plasma systems has enabled the selective recovery of materials while preventing the formation of harmful byproducts. Microwave-assisted processing has emerged as an innovative thermal treatment method that offers several advantages over conventional heating approaches.

Nanotechnology Applications in E-Waste Processing

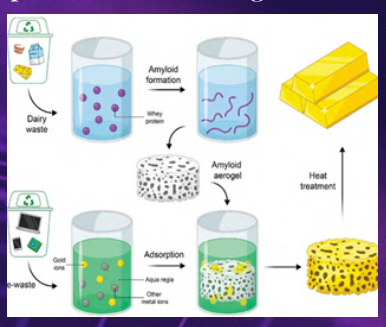
The application of nanotechnology to e-waste recycling has opened new possibilities for material recovery and processing efficiency. Nanoscale materials and processes can interact with matter at the molecular level, enabling highly selective and efficient separation and recovery processes.

Magnetic nanoparticles have been developed that can selectively bind to specific metals or metal compounds, enabling their separation from complex mixtures using magnetic fields. Nano catalysts have revolutionized chemical processing steps in e-waste recycling by enabling reactions to occur under milder conditions with higher selectivity and efficiency.



Advanced Material Recovery and Purification

The development of advanced material recovery and purification technologies has enabled the production of high quality recycled materials that can compete with virgin materials in terms of purity and performance. Electrochemical processing techniques have been refined to enable the selective recovery of metals with extremely high purity levels.



Membrane separation technologies have found increasing application in e-waste processing, particularly for the purification of solutions containing dissolved metals. Advanced membrane materials with precisely controlled

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Advancement in Recycling Technologies of E-Waste

pore sizes and surface properties can selectively separate different metal ions based on size, charge, or chemical affinity.

Crystallization and precipitation processes have been optimized using advanced process control systems and novel chemical additives to produce high-purity metal compounds and salts. These processes can be designed to selectivelyprecipitate specific metals while leaving others in solution, enabling highly efficient separation and purification.

The outstanding capability of Protein Amyloid Fibrils (AF) as an adsorbent for removing heavy metals from water has been reported only recently, but since then, extensively documented and investigated. AF are novel nanofibril materials with distinct properties such as a high surface-to-volume ratio and highly modular surface functionality.

Blockchain and Traceability Technologies

The implementation of blockchain technology in e-waste recycling has introduced unprecedented levels of transparency and traceability to the recycling process.

Blockchain systems create immutable records of each step in the recycling process, from initial collection through final material recovery and sale in accordance with compliances of environmental regulations, verifying the authenticity of recycled materials.

Conclusion

The future of e-waste recycling technology promises even more revolutionary advances that will further improve efficiency, environmental performance, and economic viability. Quantum computing applications are being explored for optimizing complex recycling processes and material flows. Advanced biotechnology applications are being developed that could revolutionize material recovery processes. Engineered enzymes and microorganisms are being designed to selectively break down specific materials or extract particular metals with unprecedented efficiency and selectivity. The integration of automated disassembly systems, advanced sorting technologies, and precision material recovery processes has transformed e-waste recycling from a labour-intensive, low-efficiency operation into a highly automated, data-driven industry capable of recovering materials with purities that rival those of virgin materials.

Dr. Sandip Chatterjee

Professor: Indian Institute of Technology, Mandi
Senior Advisor: SERI
Ex. Group Coordinator: Ministry of Electronics and Information Technology (MeitY,GoI)

Artificial Intelligence (AI) Application in E-waste Recycling Sector

Artificial Intelligence (AI) has already disrupted conventional businesses with more innovative products and services that fuel modern economy. AI empowers startups to compete with established businesses and offer greater consumer satisfaction. AI is transforming in electronics waste (e-waste) recycling sector and offer process efficiency, accuracy and more environmentally benign solution. It automates repetitive, creative tasks, and reduce manpower and also optimizes processes, reduces operating cost, enhances agility and profitability.

The manual sorting, dismantling and segregation in informal sector are inefficient methods and not sustainable. It also poses a significant threat to health and environment. Contaminated recyclable materials are a great challenge in e-waste recycling due to high levels of rejection. AI detects materials that are difficult to identify by manual sorting, like different types of plastics or composite materials, which are lost in process due to their complexity. Recycling industries are thus increasingly relied on AI tools to improve efficiency, accuracy, and sustainability.

Highlights of process improvement are mentioned below:

Reform in Manufacturing Sector

Improvement in Circular Model: AI plays a key role in tracking the material lifecycle from consumer to the recycling facility and beyond that helps create more effective circular economy models, ensure materials reusability and efficient recycling.

Design of Product: AI plays a pivotal role in design optimization, optimizing the use of materials, waste minimisation during manufacturing as well as after end of life, including easier to disassembly and recycling. It also proposes alterative design to develop more sustainable products, reduce waste and improve the effectiveness of recycling.

Secondary Material Supply Chain: AI-driven platforms on recycled materials assist both manufactures and recyclers for effective coordination on recycled material supply chain, matching the needs of specific materials in order to create a robust circular economy marketplace. AI can forecast market demand for recycled goods by ensuring a steady flow of supply and demand.

Assistance in Extended Producers Responsibility (EPR) Obligations: By continuously assessing regulatory changes through data-based interpretation of amendment of rules, AI can help producers to stay informed and quickly adapt to regulatory updates. AI-powered chatbots or virtual assistants can navigate real-time complex EPR requirements and help producers to stay up-to-date on their obligations.

Reform in Recycling Sector

Supply Chain and Inventory Management: AI model predicts inflow of e-waste feed based on consumer trends, warranty periods, and tech obsolescence. This predicts to optimize logistics and storage of waste based on recycling facility capacity and material value. AI analyses waste-related data on material composition, contamination levels and recycling rates.

Fast data analysis helps in assessing more efficient recycling processes after optimizing collection routes. Recycling facilities are benefited to maximize their output and minimize contamination. Predictive analytics to forecast waste generation, optimization of resource allocation, improving efficiency are the key for future growth of recycling sector.

Robotics and Automation: AI guides robotic dismantling systems effectively disassemble complex devices (phones, laptops) without damaging valuable components and also able to detect screws, batteries, and hidden circuits via AI-enhanced visual inspection.

E.g. Apple's robot "Daisy" uses AI-driven robotics to disassemble iPhones efficiently.

Smart E-waste Sorting: AI-powered robotic systems and computer vision can identify and sort different types of materials like plastics, metals, glass, etc., and improve both speed and accuracy. AI-powered vision systems can efficiently separate components like circuit boards, plastics, metals, and batteries from mixed waste and offer more precision over manual sorting methods. AI control robotic arms effectively separate hazardous materials from reusable parts. AI-enabled optical sorters can effectively identify precious metals or lithium-ion batteries for targeted extraction.

Material Recovery Optimization: AI algorithms predict best recovery methods for extracting precious metals like gold, silver, cobalt, etc. Real-time data optimizes chemical or mechanical processing for maximum yield.

Data Destruction and Privacy: As data becomes sensitive, AI can verify complete erasure of data before resale or recycling of devices and also detect data remnants or potential privacy breaches automatically.

AI Driven Quality Control: AI-powered cameras and sensors undertake real-time and continuous monitoring the quality of sorted materials, which help operators to detect flaws, track the purity of sorted materials, and even prevent contamination that canreduce the effectiveness of the recycling process. Prompt identification of defective items or improperly sorted materials on production lines helps in maintaining the quality of the end product.

Predictive Maintenance of Recycling Machinery: Monitoring equipment performance to detect early signs of failure are efficiently being carried out through AI models, which help in reducing machine downtime and increase operational efficiency using predictive analytics.

Efficient Policy Making

Data Analytics for Policy and Planning: AI can analyze large-scale data on e-waste generation, recycling rates, and material flows to guide policy-making and urban mining initiatives and also support circular economy models through lifecycle analysis.

Environmental Monitoring and Compliance: AI can effectively track toxic emissions or leakage from recycling processes, which ensure adherence to environmental regulations using smart sensors and AI-based compliance tools.

Extended Producers Responsibility (EPR) Compliance: AI improves efficiency and effectiveness of monitoring of Extended Producers Responsibility (EPR) compliance by automating the processes, predicting risks, improving transparency, and enhancing data analysis. AI assist producers, regulators, and consumers alike in ensuring that EPR regulations are met and that environmental impacts are minimized.

Effective Regulatory Measures: AI interprets evolving EPR regulations across different regions and jurisdictions. AI systems monitor changes in EPR laws and regulations and provide automated alerts when significant changes occur. Using AI tools, the policy makers can evaluate the regulatory gap and challenges based on comparative analysis of global best practices, which will lead to effective amendment of existing EPR regulations.

Conclusion

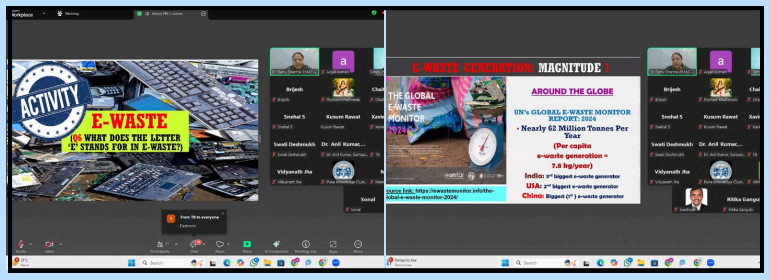
It is worth mentioning that e-waste management in India has a significant challenge, however, AI has a potential to transform this sector from a complex, polluted informal driven operation into an automated, data-driven practices, which will fuel recycling businesses further growth and higher profitability. Collection, sorting, segregation and recycling process would be highly efficient and effective. Technology intervention in e-waste recycling would generate new employment in software solutions, automated machines, training etc.

Finally, AI driven EPR monitoring and decision-making will bring transparency in the system and would immensely benefit both the producers and recyclers to discover the justified EPR cost and mitigate a long-standing mistrust. Investment on expensive machineries would then empower recyclers to showcase their performance and honesty for state of art environmental-friendly recycling process. This would also strengthen regulator to reward the performers and punish the non-performers. This transparency will further strengthen nation's commitment to recover the secondary raw materials to support future manufacturing sector and also boost the circular economy in e-waste sector.

#BeAGreenWarrior: Our Umbrella Campaign For Sustainability

Awareness-Cum-Sensitisation Drive For Mobilising The Youth And Community

During April-June (2025), the following twelve green warrior institutions have joined our green campaign and actively collaborated in organising the below mentioned e-waste awareness-cum-sensitisation drives, for mobilising the youth and community, including industry professionals.



20th June, 2025: Online Interactive Session for Industry Professionals, NGOs, Students, Recyclers and Start-up Founders, in Collaboration with Pune Knowledge Cluster (PKC: SUST-EN Public Talk Series)

8th June, 2025: E-waste Awareness-cum-Collection Drive for RWA Members and Residents of Defence Colony Association (DCA RWA: A-Block, Defence Colony New Delhi)

7th June, 2025: E-waste Awareness-cum-Collection Drive for RWA Members and Residents of Noida Sector-15 RWA (Noida, U.P.)

5th June, 2025: E-waste Awareness-cum-Collection Drive for RWA Members and Residents of Malibu Towne RWA (Sector-47 Gurugram, Haryana)

5th – 7th June, 2025: E-waste Awareness-cum-Collection Drive for the Residents of Jaipur, supported by Department of Environment and Climate Change- Government of Rajasthan, Rajasthan State Pollution Control Board and Havells India Ltd

3rd June, 2025: Hybrid Interactive Session for PAN- India Staff of Radius Systems Private Limited (Phase-1, Okhla Industrial Area: New Delhi)

1st June, 2025: E-waste Awareness-cum-Collection Drive for RWA Members and Residents of Pandav Nagar RWA (New Delhi)

26th April, 2025: E-Waste Awareness-cum-Collection Drive at Sarva Priya Vihar RWA (New Delhi)

22nd April, 2025: E-Waste Awareness-cum-Collection Drive at Crest Club RWA (Sector-54 Gurgaon, New Delhi)

15th April, 2025: E-Waste Awareness Drive for the staff of Stanley Black and Decker India Pvt. Ltd. (Pune, Maharashtra)

10th April, 2025: Online Interactive Session for PAN India and Overseas Project Team of L&T Construction: Water & Effluent Treatment IC.

2nd April, 2025: E-waste Awareness Session for UG/PG Students and Faculty members of Jindal School of Environment & Sustainability, O.P. Jindal Global University (JSES-JGU: Sonipat, Haryana)

Our Sustainability Campaign

#BeAGreenWarrior

A Sustainability Initiative Towards A Greener Planet

Save Enviroment & Be A Change Maker!

#BeAGreenWarrior

Mobilising the youth and community to take up LiFE actions and green lifestyle for environment.

#Declutter4GreenImpact

#Declutter4GreenImpact

Mobilising community to declutter their spaces and to send the piled-up e-waste for formal recycling, thereby contributing towards Circular Economy and Swachh Viksit Bharat!

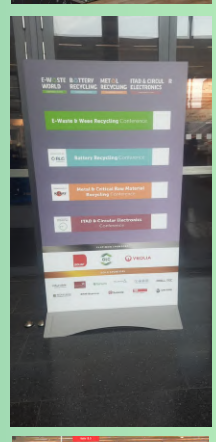
Stakeholder Workshop By RSPCB

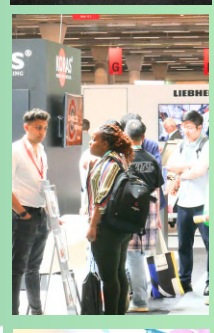
H.M.E team was honored to participate in the program organized by RSPCB- Jaipur. The event was focused on strengthening the EPR framework and advancing technologies in e-waste recovery.

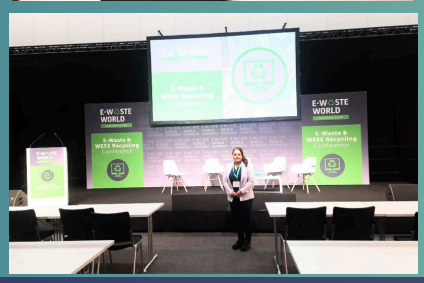
WORLD ENVIRONMENT DAY CELEBRATION: E-WASTE COLLECTION DRIVE IN JAIPUR CITY

H.M.E. team joined the green drive launched by Hon'ble CM- Shri Bhajan Lal Sharma, supported by Rajasthan Environment Dept., RSPCB, and Havells India Ltd.

GLOBAL EXPLORATION FOR LEARNING BEST PRACTICES AND INNOVATION IN WEEE







H.M.E. Team joined E-Waste World Conference and Expo- 2025 (Frankfurt, Germany) to explore global best practices and innovations in e-waste recycling.

SPECIAL THANKS TO OUR SUSTAINABILITY PARTNERS

Panasonic · StanleyBlack&Decker · CASIO · Labcare · LUMILEDS · passion to lead EPSILON · SMA · OSR EQUIPMENT SERVICES AND SOLUTIONS · Rx Infotech P Ltd · OSRAM · DAMIER · ESTEX TELECOM · SEMITECH · SAISTAR · SCJ · ASTA TECHNOLOGIES · LFORCE LIFE · Dolphin हमसे है Embroidery · LUOKE HRK SEWING MACHINERY SINCE : 1996 · D R ENGINEERING · Melody Media · ARHAM TECHNOLOGIES LIMITED · ideal POWER TOOLS

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