M.Tech. Program on "E-waste Resource Engineering & Management"
(to be jointly executed by IIT Hyderabad and C-MET)

Background: With rapid change in technology and more digitalization in the world, there is an explosive growth in electronics industry and subsequently that has led to enormous growth in electronic waste (e-waste). E-waste contains many hazardous and toxic substances which have serious health and environmental effects, if not managed properly. Therefore, it becomes essential to learn about various technological interventions to manage, reduce and recycle e-waste for its safe disposal.

Objectives: This proposed M.Tech. program on E-waste resource engineering & management is not only very timely but also a very unique with joint participation from IIT Hyderabad and Centre for Materials for Electronics Technology (C-MET), Hyderabad. This M.Tech. program will first discuss the Waste management in general and e-waste management in particular including E-waste management rules. Various technologies for recycling of e-waste including the recovery of metals, plastics will be studied in detail followed by understanding life cycle analysis and carbon foot print calculations. Chain and supply management including the role of Artificial intelligence based techniques to develop an effective recycling system will also be covered. Few case studies will be taken in seminar course while the thesis work will facilitate in developing new technological and viable solutions to meet the challenges in E-waste management.

Recycling of e-waste needs expertise in three areas: (1) collection, recycling and / or reuse of Waste Electrical and Electronic Equipment (WEEE) and its sub-assemblies (2) expertise over the entire life cycle of electronic devices and lastly (3) Non-ferrous and precious metals recovery in an environmentally friendly manner. Similarly, the life cycle management needs (a) analysis of the life cycle logistics (manufacturing, distribution, collection, dismantling, recovery), (b) analysis of manufacturing products and substitutes within the framework of e-waste (management) rules 2016 regulations with a focus on resource efficiency and lastly and (c) the carbon footprint generated by the electronic products for generation as well as recovery.

This M.Tech. program will catalyse the efforts towards E-waste management in the country and worldwide and will provide a necessary support for several of Government initiatives in this direction such as Skill India, Swachh Bharat, Waste-to-Wealth initiatives.

Eligibility:
B.Tech. in Chemical Engg./Materials Sci. & Metallurgical Engg./Civil Engg./Environmental Engg./Electrical Engg./Mechanical Engg./Engineering Sciences/Engineering Physics/Minerals Engineering and affiliated areas with GATE qualification OR M.Sc. in Physics/Chemistry with NET/GATE qualified

GATE paper qualified: CE/CH/CY/EC/EE/IN/ME/MN/MT/PH/PI/XE-C/XE-F/XE-H/XL-P/

Note: NET/GATE qualification is exempted for industry sponsored candidates with a minimum two years' experience OR for IIT Undergraduates with minimum CGPA of 7.0.

Intake: 05

M.Tech. Program on "E-waste Resource Engineering & Management"
(to be jointly executed by IIT Hyderabad and C-MET)

Program Structure:
Total: 50 credits (Theory 24+2 credits; Thesis: 24 credits)
Theory: 14 Core credits + 10 Elective credits + 2 Core credits Institute courses

Semester wise credit requirements:

Semester	**Theory**		**Thesis**	**Total**
	Core	Elective		
I	6 (3+3) **+ 1**	5 (3+2)	Nil	11+1 (12)
II	8 (3+3+1+1) **+1**	5 (3+2)	Nil	13+1 (14)
III	Nil	Nil	12	12
IV	Nil	Nil	12	12
Total (I-IV)			24	48+2 **(50)**

Semester wise Theory courses:

Semester I (12 credits)
Core Courses (7 credits; 3+3+1):
1. Introduction to waste management (3 credits) **(CMET)**
2. E-waste Recycling Methods (3 credits) **(CMET)**
3. English communication (1 credit) (IITH)

Elective Courses (5 credits; 3+2):
A. Choose any one (IITH) (3 credits)
A1: Electrometallurgy (3 credits)
A2: Numerical Methods (3 credits)

B. Project, business & human resources management (2 credits) (Choose any one out of two offered from this list) (CMET)
B1: Design concepts of project capacity to a viable scale
B2: Business calculations and break-even point
B3: SWOT analysis and risk management
B4: Updated Government policies on E-waste management

Semester II (14 credits)
Core Courses (9 credits; 3+3+1+1+1):
4. Instrumentation and Characterization (3 credits) **(CMET)**
5. Chemical Hydrometallurgy: Aqueous Processing of Metals (3 credits) **(IITH)**
6. Supply Chain Management and Circular Economy (1 credit) **(IITH)**
7. Introduction to Artificial Intelligence (1 credit) **(IITH)** (To be offered as a common course by AI department)
8. Industrial Lectures Series (1 credit) **(IITH)**

Elective Courses (5 credits; 3+2):
C. Choose any one (IITH) (2 credits)
C1 Queuing Theory
C2: Detection and Estimation Theory
C3: Molecular Thermodynamics

D. Plant Design and Instrumentation (3 credits) (CMET) (Choose any one)

D1: Pilot plant designs, Mechanical engineering designs

D2: Instrumentation for efficient recycling and automation

Theory credits: 26 (12 Credits by IITH Faculty and 14 Credits by C-MET Scientists)
Course Details:

Semester I

Core Courses

1. EW5010 - Introduction to Waste Management (3 credits)

Waste Electrical and Electronic Equipment (WEEE): Flows, Quantities and Management, a Global Scenario; The Importance of Waste Management; Types of Waste- Solid and Liquid; Criteria for EEE/E-Waste Classification; Multivariate Model for E-Waste Estimation; Environmental and Health Effects of Waste Management, Inventorisation of E-Waste and Emerging trends in E-waste disposal with bench marks for depollution - global scenario; Dumping, Burning and Landfill: Impact on the Environment; Effective Waste Management and Disposal Strategies; Legislative Influence on Electronics Recycling; Waste Management Rules and Their Amendments; Electronic Waste: Public Health Implications; Restriction of Hazardous Substances (RoHS) Directives in Electrical and Electronic Equipment; 3R's of Managing Solid Waste: Reduce, Recycling and Reuse; Electronic Waste Management Rules 2016; Extended Producer Responsibility (EPR) in E-Waste Management; The Role of Collective versus Individual Producer Responsibility in E-Waste Management; Recycling and Resource Management: Ecological and Economical Valuation; Life Cycle Assessment (LCA) Approach to Waste Management System; Environmental Incentives for Recycling and Life Cycle Analysis of Materials Recycling

Text book:

i) Electronic Waste Management and Treatment Technology, Editors: Majeti Narasimha Vara Prasad Meththika Vithanage
ii) Electronic Waste Management, Edited by R. E. Hester, R. M. Harrison, RSC Publishing 2009
iii) Solid Waste Technology & Management, Christensen, T., Ed., Wiley and Sons., 2011
iv) Electronics Waste Management: An India Perspective. Front Cover. Sandip Chatterjee. Lap Lambert Academic Publishing GmbH KG, 2010 - Electronic
v) Handbook of Electronic Waste Management, International Best Practices and Case studies, Elsevier, 2019
vi) E-waste: Implications, regulations, and management in India and current global best practices. Author(s): Rakesh Johri, TERI Press
vii) The global impact of e-waste: Addressing the challenge by Karin Lundgren, Publications of the International Labour Office Geneva, Switzerland, 2012
viii) E-Waste in Transition: From Pollution to Resource edited by Florin-Constantin Mihai, InTech, Croatia 2016

Reference Book:

i) Electronic Waste Management and Handling Rules, Ministry of Environment and Forests, Government of India, New Delhi, 2011
ii) Guidelines and criteria for hazardous waste landfills and hazardous waste treatment disposal facilities, Central Pollution Control Board, New Delhi, 2010

Outcome of this course: Overall understanding about E-waste Management rules 2016 and strategies for e-waste management.

2. EW5020 - E-waste Recycling Methods (3 credits)

Recycling Electronic Waste: Challenges and Opportunities for Sustainable Management; Resource Recovery from E-waste: Efficiency and Circular Economy; Materials Used in Manufacturing Electrical and Electronic Products; Integrated Approach to E-Waste Recycling: Recycling and Recovery Technologies, Emerging Recycling and Recovery Technologies, Printed Circuit boards; Sector-based Eco-Design; Theory of Physical Metallurgical Processes: Ellingham Diagrams, Exothermic Processes; Pyrometallurgical Process for E-waste Recycling: Pyrolysis, Depopulation, Calcination, Smelting; Flux Chemistry for Separation of Metals; Hydrometallurgical Process for E-waste Recycling, Separation and Purification of Metals; Fundamental Principle and Practices of Solvent Extraction for Extraction and Separation of Rare Earth Metal(s); Permanent Magnets Scraps Treatment for Rare Earth Metal(s) Recovery; Lithium Ion Batteries: from Devices to Recycling; Rare Earth Metal(s) Extraction from Florescent Lamps; Physical and Powder Separation Techniques: wet and cold grinding, density separation, separation in the presence of magnetic field, solvent extraction, etc; Management of Effluents: Solids, Liquids and Gases Neutralization; Instrumentation and Automation of Pyro-Metallurgical Processes; Characterizations and Classification of E-Waste: Sampling Techniques; Technical and Societal Aspects of E-Waste Treatment; Overview of Indicators for Evaluating the Performance of E-Waste Treatment; Best -of-2-Worlds (Bo2W) Approach for E-Waste Treatment

Text book:

i) Electronic Waste Management and Treatment Technology, Editors: Majeti Narasimha Vara Prasad Meththika Vithanage
ii) Electronic Waste Management, Edited by R. E. Hester, R. M. Harrison, RSC Publishing 2009
iii) The Complete Technology Book on E-Waste Recycling, Asia Pacific Business Press Inc, 2018
iv) Electronic Waste Management: Edition 2Editors: G H Eduljee, R M Harrison, Royal Society of Chemistry.
v) Extractive metallurgy of copper by AK Biswas, W.G. Davenport
vi) E-Waste in Transition: From Pollution to Resource edited by Florin-Constantin Mihai, InTech, Croatia 2016

Reference Book:

i) Handbook of Electronic Waste Management: International Best Practices and Case Studies 1st Edition, Eds. Majeti Narasimha Vara Prasad, Meththika Vithanage, Anwesha Borthakur

Outcome of this course: Understanding about various e-waste recycling methods and strategies, resource efficiency and circular economy

Elective Courses

A1. MS 5390 Electrometallurgy (3 credits)

a. Fundamental aspects of Electrometallurgy: Introduction (Electrometallurgy, Electrochemical principles and basic concepts, Evolution of electrometallurgy), Pourbaix diagrams, Transport properties of electrolytes (aqueous, molten and ionic solutions), Solution models (Debye-Hückel-aqueous, Temkin-molten salts), Electrode-electrolyte interface, Equilibrium electrode potential, and Potential Applications (Electronics, Automotive, Aerospace, Biomaterials & Medical Devices)
b. Electrochemical Kinetics: Electrochemical reaction kinetics and mechanism of electrodeposition, Mass transport and interfacial processes, Aspects of cementation, electrocrystallization and surface morphology of metal electrodeposits (through mathematical approach, physical model, and a realistic system), Current distribution in electrochemical cells, Electrodeposition at a periodically changing rate, Effects of additives
c. Various Electrometallurgical Processes: Electrowinning (melts electrolysis and aqueous solution electrolysis), Electrorefining (from impure metal anodes), Electroplating (metals, alloys and composites) from aqueous electrolytes, ionic liquids, & molten salts, Electroforming, Surface finishing (Electropolishing, Electromachining)
d. Electroless Deposition (Displacement deposition, Contact deposition and Autocatalytic deposition)
e. Structure, Properties and Characterization of Electrodeposits
f. Case Studies, Industrial Practices & Challenges (energy utilization, chemical stability, productivity, and safety), Materials and Environmental issues, Industrial/Electrochemical Effluents/Wastewater Treatment
g. Electroplating: Numerical Modelling and Simulation
h. New age Electrodeposits (nanostructures, multilayers, multicomponent, etc)

Books/References

(1) Fundamental aspects of electrometallurgy, by K.I. Popov, S.S. Djokic and B.N. Grgur, Kluwer, Academic Publishers, 2002
(2) Fundamentals of electrochemical deposition, by M. Paunovic and M. Schlesinger, Wiley Interscience, 2006
(3) Modern Electrochemistry (Volume 1), by J.O'M. Bockris and A.K.N. Reddy, Plenum Press, London, 1970
(4) Understanding Voltammetry (Third Edition), by R.G. Compton, E. Laborda and K.R. Ward, World Scientific Publishing Europe Ltd., 2018
(5) Understanding Voltammetry: Simulation of Electrode Processes, by R.G. Compton and C.E. Banks, World Scientific Publishing Europe Ltd., 2018

A2. Numerical Methods (3 credits) CH5010

Review of computer programming; simultaneous linear algebraic equations, Gauss elimination, partial pivoting, LU decomposition, matrix inverse, Gauss-Seidel method, relaxation, Eigen value calculations, roots of nonlinear equations, successive substitution, Newton's method, single variable / multiple variable methods, functional approximation, curve-fitting, linear and nonlinear regression, Newton's forward and backward difference interpolation, Lagrangian interpolation, Pade and cubic spline approximations, numerical differentiation and integration.

Text / Reference Books:

1. Numerical Methods for Engineers by Prof. S. K. Gupta, 5-th Ed., New Age International, 2010.

B. Project, business & human resources management (2 credits)

(Choose any one out of two offered from this list)

B1: EW5100: Design concepts of project capacity to a viable scale (2 credits)

Concept of Technology Readiness Levels (TRL); Project Management; Technology Commercialization: Role of Incubator, Cluster, Research Park and Consortia; Intellectual Property Protection and Management; Technology Assessment: Valuation and Pricing; Technology Development and Management; Measuring Commercialization Capability: Capital expenses, Revenue calculation; Building Commercialization Capability; Technology fusion; Sustainable Production Technologies; Case Study: Spent PCB recycling, Scale-up to Commercial Scale Recycling, Case Study: Rare Earth Recovery from Spent Permanent Magnets; Case Study: Recycling of Li ion Batteries; Availability of Raw Material and Consistency

Reference books:

i) Technology Commercialization Manual: Strategy, Tactics, and Economics for Business Success edited by Melvin Joseph DeGeeter
ii) E-Waste in Transition: From Pollution to Resource edited by Florin-Constantin Mihai, InTech, Croatia 2016

B2: EW5110: Business calculations and break-even point (2 credits)

Entrepreneurial Opportunities: Dismantlers, Recyclers, Refurbishers, Process Equipment Manufacturer, Refractory Manufacturer; Planning and Marketing: Developing an Effective Business Plan, Pricing Strategies; Energy Considerations and Economic Incentives for Recycling and Resource Recovery; Evaluating and Managing Financial Performance; Capital expenses: Land, Plant and Machinery; Installation and Commissioning of Equipment and/or Process; Operational expenses: Human resource, Raw Material, E-Waste for Recycling, Utilities, Logistics, Marketing, Contingency, Spares and consumables; Revenue calculation for recycling of different Waste Electrical and Electronic Equipment (WEEE): Complete platinum-group metals (PGM) recovery, Partial PGM recovery, Refurbishment, Rare Earth Metals Recovery; Case study: Spent PCB Recycling 100 kg and 1 Ton/day capacity; Case Study: Rare Earth Recovery from Spent Permanent Magnets; Case Study: Recycling of Li ion Batteries

Reference books:

i). Small Business Management: Launching and Growing New Ventures by Justin Gooderl Longenecker

B3: EW 5120: SWOT analysis and risk management (2 credits)

SWOT Analysis: Steps for Success with The SWOT Analysis; Influencing Factors; SWOT analysis of E-Waste sector in India; Strength: Statistics of E-Waste Generation, Demand and Need of Recycled Materials, Business Opportunities; Weakness: E-waste channelization, consumer unawareness, lack of research, poor implementation of E-waste management rules, high capital expenses for setting-up recycling facilities; Opportunity: Environment Friendly E-waste recycling, Difference between E-waste generated and recycled, start-ups in various fields of E-waste management, formalization of informal sectors; Threats: lack of E-waste awareness, Illegal processing of E-waste, health hazard and unhygienic working conditions, cost competence with informal route recycling, Effluents Management

Risk Management: Risk Assessment Standards and Definitions; Risk Assessment Fundamentals; Fundamental Hazard Analysis and Risk Management: Informal Methods, Formal Methods; Industrial Hygiene Risk Assessment: Occupational Health Risk, Health Risk Assessment and Prioritization; Machine Risk Assessment: Machine Safety Standards, Machine Safeguarding, Assessment of Machine Maintenance and Service

Reference books:

i) The SWOT Analysis: A key tool for developing your business strategy by Christophe Seth, Published by 50MINUTES.com

ii) Risk Assessment: A Practical Guide to Assessing Operational Risks, edited by Georgi Popov, Bruce K. Lyon, Bruce Hollcroft, WILEY

B4: EW5140: Updated Government policies on E-waste management (2 credits)

E-Waste Management Rules and Amendments: Definitions of key terms; Legislation and Policies on Health Care Waste Management; E-Waste Auditing;; Authorised Recycler's Registration; Pollution Control Strategies: Guidelines for E-Waste Recycling; Responsibilities of Manufacturers, Producers, Collection Centres, Dealers, Refurbishers, Consumers, Bulk Consumers, Dismantler, Recyclers; Procedures for Seeking and Grant of Authorisation, Reduction in the Use of Hazardous Substances in Electronics Equipment; E-Waste Management in Europe, Japan, South Korea and China

Reference books:

i) Handbook of Electronic Waste Management: International Best Practices and Case Studies 1st Edition
Eds. Majeti Narasimha Vara Prasad, Meththika Vithanage, Anwesha Borthakur

ii) Electronic Waste Management and Handling Rules, Ministry of Environment and Forests, Government of India, New Delhi, 2011

Semester 2:

Core Course:

EW 5060: Supply Chain Management and Circular Economy (1 credit)
Introduction to Supply Chain Management - Logistics Network Configuration - Inventory Models - Value of Information - Circular Economy - IT & Decision Support - Mathematical Models

Text / Reference Books:
1. Designing and Managing the Supply Chain: Concepts, Strategies and Case Studies by David Simchi-Levi, Edith Simchi-Levi, and Philip Kaminsky, McGraw Hill Education; 3rd edition (2007).
2. Operations Research: An Introduction by Hamdi Taha, Pearson; 9th edition (2010).
3. A Circular Economy Handbook for Business and Supply Chains By C. Weetman, KoganPage; 1st edition (2016).