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Electronic Waste : Reduce, Reuse, Recycle & Remove (R's) Concept and Approach

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Abstract: **- E waste constitutes around 2.5 to 3 % of the total waste and the remaining wastes are the solid wastes only of various varieties and are very hazardous and posing threats to health and environment living in the universe. The resources for production of EEE are limited and optimal use and reuse of resources in most economical manner should be aim for maximization of utility. This can be achieved by the proper technological application of Reduce, Reuse, Recycle and Remove concept and approach. The conventional management of waste is less technological and has to be made sustainable management system by proper embedment of technology. The socio political approach for pushing the pressure of disposal on the less developed nations by developed one is not the valid approach and needs a change in mind set. The degradation of environment and health hazards will jot see the nation's boundary and will affect the beings uniformly. The justifiable technology rich approach for preservation of resources and maximum use of products is need of hour. Change in design and processing steps for conservation of energy and green approach is day by day becoming increasingly requirement and challenging.**

Keywords: EEE, Pollution, Toxic, Recovery Chain, Reduce, Reuse, Recycle, Remove Hazards, Threats

I INTRODUCTION

The day to day life is full of invasion of Electronic and Electrical Equipments (EEE), its usefulness and dependency on and of the EEE is an established fact. As every product, it has a life and has to reduce to the end of life situation and this end of life or loosing its usefulness leads to situation where waste is generated and this EEE waste is termed as WEEE or E-waste. This e waste contains many such constituents which are not only undesirable but are toxic and hazardous. These toxic and hazardous constituents of the WEEE or e waste pose serious threat to environment and effect human health. The popular EEE contains

computers, laptops, printers televisions, VCRs, stereos, photocopiers, fax machines, electric lamps, mobile, audio equipment, batteries, electronic gadgets electronic toys and many home appliances. If these disposable popular EEE are not disposed properly it can lead to many undesired conditions and consequences. Before final disposal, the conditions of its use in terms of various R's are to be examined. The different R's means here: Reduce, Recycle, Reuse and Recovery.

In the recent past the sector which has shown tremendous rate of growth is the EEE industry. The use and automation of life style and making life easy demands the extensive use of EEE. This is two sided problem i.e. at one end it addicts the user and on the other side it generates e waste. The life span of electronic product is very small as the technology is fast changing / growing and the items gets outweighed by the benefits of the new product at one end and get replaced at other end. Frequent change leads to mishandling and ultimately reduces its utility and turns to e waste. Although, the e waste constitutes only 2.5 to 3 % of the total waste and the remaining wastes are the solid wastes only of various varieties. This is a global phenomenon and is affecting the globe uniformly. The worst effect is on the third world countries and developing nation ones.

Tackling of the e waste is developing into global phenomenon and the new approaches are day by day becoming popular and are finding own ways. The innovative design, extended producer responsibility, fixing of new standards and labels, advanced recycling, remanufacturing, reuse, redesigning and educating population about proper handling and dealing with product and wastes are new steps, talks and initiatives in this direction.

To tackle the pollution and environmental issues and settlement of particularly e wastes, the countries have enacted regulations and legislations specially for disposal, recycling and reuse for proper attention about the safety and health problems which one is to tackle properly at least form the recovered hazardous constituents from the e-wastes while recovery and recycling. For preservation of materials and optimal use of resources it is very much essential to make use of valuable materials obtainable from the disposal and recycling of e-wastes. The materials which can be saved from the e wastes are of the tune of million tons in form of ferrous, copper and other materials etc.

The developed countries have started and till date have evolved numerous approaches for tackling the e waste but the developing countries who are the champions in the e waste piling up are far behind from being in satisfactory

condition. The developing nations are also equally responsible for tackling these issues but have very less resources to adjust and in turn have to adjust for higher pollution tackling share than the developed countries. The burden of obsolete EEE handling in name of technology transfer / technological upgradation and penalty for crunch resources is the adjustment of the politico-social scenario of the current global situation. The Greenpeace has predicted that 20-50 million tones of e wastes are being generated annually. The Asian region is contributing half of the burden in the present decade and is likely to double in the coming decade. The major growth in the e waste is mainly because of growing use of computers. Globally 1000 million of computers are expected by now. The rapid growth of mobile use and its changing history across the world also gives rise to e-waste.

Development of sustainable technology for creating sustainable market in the developed and developing nations can bridge the need and reduce the e-waste. The exporting of obsolete technology in name of technology transfer is a wise step of developed nations on the shifting of possible e wastes to the underdeveloped and developing nations.

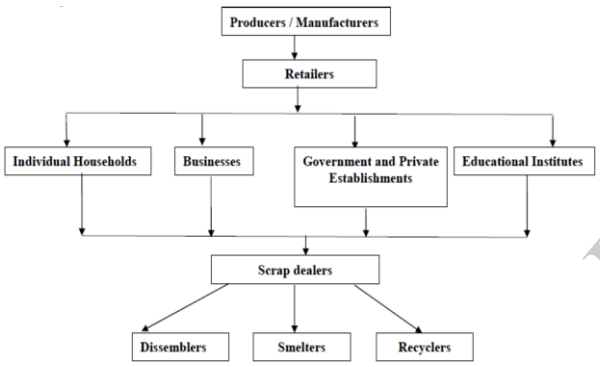

Figure Showing Indian E Waste Flow Chart

II. THE E WASTE STOCKS AND INVENTORY

The advances in electronics, electrical and modern sector of engineering i.e. information communication technology (ICT) has changed the life of common ones drastically in the recent past years. The development of the EEE and ICT has eased he life tremendously but has posed different problems to environment and near about by increasing the pollution. The growth of wastes and its management has remained a problem and the recent changing trend of EEE and ICT has given rise to new fold of wastes known as e waste. Most of the modern electronic equipments whether they are computers, mobile phones, electronic gadgets , toys etc contains important precious metals at one end and highly toxic and hazardous materials like heavy metals such as lead, mercury , copper, cadmium, cathode ray tubes (CRT) , barium, batteries, hazardous chlorinated, brominated, biologically active, acid and plastic and similar substances at other end. The current use is not a problem but at time of recycling or disposal they need special care in order to minimize the threats of environment and health. Study of Basel Action Network (BAN) shows that worldwide available 500 million computers contains 2.87 billion kg plastic, 716 kg lead, 0.2867 million kg mercury besides numerous valuable materials and elements. The other rich source of lead is the CRT monitor or CRT in television. On an average a 36 cm CRT contains 2.5 To 4 kg of lead which may mix with water and penetrate deep into the ground water through landfills and contaminate the ground water source itself.

Lack of opportunity for employment and poverty of the developing and underdeveloped nations ponders for the avenues for creation and possible opportunities of employment irrespective of working conditions and environment. The cost of disposal of wastes i.e. e-wastes in the developed nations is far larger than exporting these to underdeveloped and developing nations. The e waste handling and dismantling of EEE in general and electronic products in particular for reuse and segregation of components and valuable items coming from developed nations has become a reality these days. The disposable wastes from developed countries are finding ways to developing countries like India and similar ones mainly because of readily available manpower in throw away price. The re usable components and constituents are taken out from the incinerate e wastes. The dismantled and recoverable materials are sold for good prices and they find extensive use in the EEE industries for further manufacturing of similar types of products. The ill skilled workers or workforce performing the gathering , disassembling, cooling, recycling and recovery of valuables from the wastes in unskillful manner poses threats to self, others, environment and to increase in pollution levels affecting masses.

The export of e wastes from developed nations to poorer nations aims at reduction of pollution and maintenance of environment levels well under permissible limitations marked by the various agencies for their own situation only. In name of financial and technological assistance these developed nations extend grants for development of new initiatives for experimentation on reduction of toxicity and pollution at cost of hazards in the developing and underdeveloped nations. The grants so received facilitate in building infrastructure for research and development in these areas and will benefit the developing nations. The new paradigms and initiatives are explored and invented and ultimately the benefit goes to them only. The hazards of recycling results in larger sacrifices. The websites citing the ill-effects among the children and persons mostly engaged in the e-wastes and sometimes living around e-wastes due to dipping components in acid, spilling acids from batteries, breathing toxic fumes can be viewed from the underdeveloped nations particularly in Asian regions. The e-waste dump sites are increasing the contents of lead , mercury cadmium etc levels which are responsible for increase in pollution level which are responsible for posing increased risk of radiations causing cancer, neurological disorders, kidney damage, breath related situation or problems and many more health threats.

As per report of MAIT, Toxic link and GTZ the stock in 2005 of e waste was 146000 tons , 400000 tons in 2010, 800000 tons in 2012 with an increase with the current level will make it grow 500 % by 2020 in India. E waste inventory can be seen as mix of formal and informal sectors. The e waste dealing for redressal is done in formal and informal i.e. unorganized sectors. Most of e-wastes (to the tune of 95 %) end up in the informal sector. The hawkers of radii & waste and scrap dealers who work for local gains are mostly dealing with the sophisticated e wastes also. The unprotected and unskilled persons are handling these and ruin their own life, environment and cause grave concerns to the pollutions of atmosphere including the air and water by unknowingly dumps in the open and contaminating the ground water even.

Worldwide every year 20 to 50 million tons of e-waste are generated. Only 13 % e-wastes were recycled in 2009 which amounted to around 53 million tons. The e waste due to computers by 2020 will increase to 200 – 400 % in S Africa and China and by 500 % level in India from the 2009 data. By end of 2015 the use of computers is expected to touch 2 billion worldwide out of which the major share will be of emerging giants like India , China, Brazil and Russia.

III. THE LIFE CYCLE & IMPORTANCE OF DIFFERENT R'S

The **Reduce , Reuse , Recycle and Removing** are the basic **R's** approach in the management of EEE products in particular and its optimal use specially when we talk of environment friendly alternatives in dealing with the growing generation of product and its e-wastes vis-a-vis its impact on health, economy and natural ecosystem of the universe.

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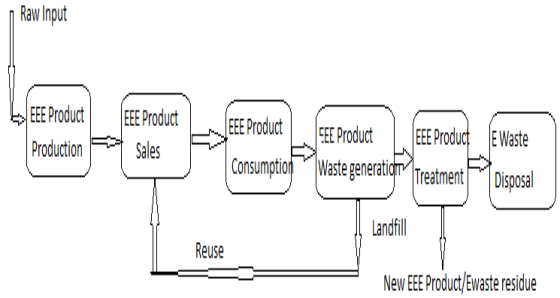

Figure Showing Typical EEE Product Life cycle and Reuse and Disposal

The third R factor is the **Recycling** stage. It can be material or thermal recycling depending on the product type and resources and component and constituent we are considering. The main strategy is for the items which cannot be reused as resource. The items which are discarded but have re-utility can be put to recycling and once again they give rise to development or birth of resource. In the thermal recycling consideration is on the items which has no alternatives other than incineration and material recycling is not possible from these. The materials have to segregated

In case of Production i.e. Manufacturing, Re manufacturing, Distribution and even Disposal of EEE we must focus on the various R factors.

Reduce or reduction of resources of any type, as reduction in use will lead to availability for more product manufacturing and more for use. Here the reduction can be termed as activity to minimize the use of resources by integration of technologies in production of the product also. The integration of systems will lead to higher efficiency and lessening of transmission loss which will improve efficiency of product and at same time will increase life span of product. The reduction of use of resources is vey well applicable in reduction of wastes also. The waste what we obtain after use can be subjected to such treatment that the possible useful materials can be extracted and reconditioned and once again put to use and will also come under reduction.

The second R factor is the **Reuse** where emphasis on repeated use is premilarly stressed upon. The cycle of reuse is multidirectional. In one way one can stress that while product is put to extensive use it loses its utility and reduces its life and nears the end of life and in this situation the extraction of materials for reutilization of fresh production can take place. In other thought one can see that while manufacturing or producing the product the left out resources have ample scope of its utilization for newer smaller products in case of metal or plastic plates or sheets or similar one. If one utilizes the resources in optimal manner the utilization of resources will lead to better growth and reduction in possible wastes. Here we use the resources repeatedly and optimally carving the usefulness from the waste of one process well suited for reuse or for final dump in the landfills or treatment for final goodbye.

The fourth R factor is the **Removing** or disposal stage. The constituents, components or items which have become such that it cannot be put to use by any means have the only option left of removal or disposal. The removal or disposal of unusable EEE products are highly skilled activity and requires technology and better advanced know how. The toxicity and hazardous of the wastes present are the main source of environmental degradation and sources of air , water , or other types of pollution and sources of possible health and hazards threats.

In a broader look the recovery of the resources is the main aim and this can be typically viewed as the mentioned recovery chain.

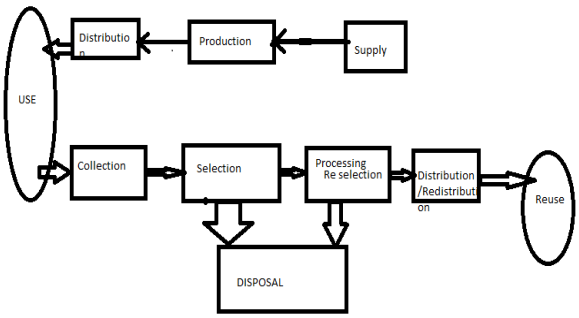

Figure showing A Typical Recovery Chain Illustration

The life cycle of a typical EEE product or any product can be summarized as

Arrangement of resources, may be natural or manmade

Processing of needed and acquired resources

Optimal Products Design and Optimal Selection of Resources / Inputs

Product/ Services Assembly or Production

Product / Services Distribution through network for availability

Utilization of Product from end user

Collection of utility loosing products and Reuse of components / constituents

Recycling of products or possibly accepted wastes from consumption or production

Removal / Disposal of remains or residuals from the wastes

The relation of Reduce, Reuse, Recycle and Remove on constituents and affects can be visualized in the table mentioned herein

The R segment	**Fields**	**Actions achieved**
Reduce/ reduction	Waste reduction Production volume reduction Waste reduction for disposal	Reduced energy requirement for destruction of waste Energy consumption reduction Fumes and toxic gas generation reduction
Reuse	Waste reduction Production volume reduction Waste reduction for disposal	Reduced energy requirement for destruction of waste Energy consumption reduction Fumes and toxic gas generation reduction
Recycle	Waste reduction Production volume reduction Waste reduction for disposal Production process change Alternate energy Back to Resource	Reduced energy requirement for destruction of waste Energy consumption reduction Fumes and toxic gas generation reduction Energy consumption reduction Reduction of energy Disposal amount reduction
Remove / Dispose	Waste volume reduction Alternate energy Waste reduced permanently Toxic and hazards emission	Properly removal reduces wastes Production of energy if able to use Less volume and environment toxicity Pollution and exposer to hazards

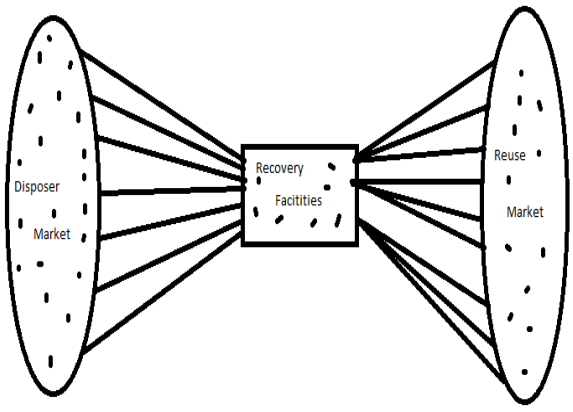

Figure Showing Illustration of a Typical Resource Recovery Network

IV. CONVENTIONAL AND SUSTAINABLE WASTE MANAGEMENT:

The waste management can be viewed in traditional and technological ideological prospective. The consequences of the conventional management of wastes leads to minimal or Limited efforts on minimization of wastes at source, mostly improper method of segregation, very crude and limited approach of collection resulting in poor collection, dumping of wastes in unscientific and illegal ways as per new regulations which have addressed the waste considerations these days, dumping in open without caring for environmental concerns and burning in open which produces fumes and can lead / causes serious health hazards, employing limited unskilled or semi skilled or unskilled professionals from the formal or informal sectors including limited involvement of private sector and communities which are basically responsible for wastes , no or very uncared integrated approach, conventionally thinking that the wastes have no residual value and most importantly the deprivation of local services of governmental or municipal agencies. The conventional managements of wastes are the natural outcome of the civilization to do away with the unwanted ones.

The aim in sustainable management is for minimizing the hazards and threats in scientific and regulated ways. Traditionally we don't value wastes and think that they have lost all its usefulness and discarded ones at the end of pipe in a first in first out. The focus is mainly on collection and selection of sites where it can be dumped without reasoning the possible degradation of environment. The proper adequate saving for better economic considerations and consideration for resource when added to the traditional conventional waste management it can lead to situation for increased resource efficiency by minimization of maiden resource i.e. source reduction. Prevention of environmental degradation by minimization of waste through eco-friendly designs and products when added to management it can lead to a fruitful situation. Development of chain organizations which results in such organizations where ones discard or left-out/ rejection becomes resource of other i.e. industrial symbiosis can lead to situation where an organized processing chain is formed to reduce waste can be viewed as adding another feather in the conventional management system of waste or development of sustainable waste management.

The major threat of the improper waste management is towards environment degradation and threat towards health and in this case as the informal sector is contributing management of 95 % of the wastes so it is better to acknowledge it and analyze it. The local communities living near the waste dumps can be susuptable to the following risks if precautions and protective measures are not followed:

The common health problems can be listed as contamination of jagged metals can lead to tetanus

The improper disposal of Printed Circuit Boards can lead to smoke and fumes which can be toxic and harm the nervous system ,

Lead presence and contamination results in neural infection and damage in general.

The uncared management of waste can lead to violence, untimely adult behavior , stress , anxiety, skin ailment , gastric, gastrological problems , respiratory problems development of water born desaise like malaria as the waste dumps often serves as breeding places of mosquitoes and insects etc

Role of informal sector in waste management is loud enough. Studies suggest that at present workers working in the informal sector of recycling of wastes is around 15-18 millions which roughly constitutes around 1 % of the global population. The involvement of this sector with the formal sector can result in win-win situation as this will influx the needed technology in waste management. The best one can see is enhanced recycling rates in technological manner, saving of resource thereby causing huge reduction in waste, saving of capital and generation of employment to vast number of workers under categorically improved working conditions.

The demand of the hour for effective management of e-wastes is basic change in attitude and our mindset. We must treat waste as resource. Establishment of linkage between waste and resources has to be properly thought of and applauded at one end and emphasis on downstream waste management with efforts for upstream resource Management for reduction of wastes on other hand can give a boost to the efforts.

The performance and standard indicators of conventional and sustainable improvement for waste management can be various. Without indicators working is useless hence some indicators for qualitative indications betterment to assess resource efficiency are essential and its fulfillment can be viewed under these parameters

- Reduction of virgin material for total volume production.
- Reduction of potential recycled materials
- Reduction in energy requirement for production and processing
- Increased productivity by materials productivity based on ratio of economic output to material input piece wise
- Efficient and improved energy productivity
- Reduction in waste production and reduction in waste disposal in terms of economic output in terms of per unit of material disposal

- Increase in ratio of resource input per unit of end-user service to assesses resource use against the useful function gained and maintained for the macroeconomic indicator etc..

The recent trend for change of mindset globally as initiative can be seen as experiments of Japan in terms of recycled based / sound material cycle based societies, Green growth initiatives in Korea and Circular economy in China etc.

V. THE GOVERNMENT AND REGULATING AGENCIES STRATEGY AND EXPECTATIONS

In the Present scenario the strategy and expectations of the stocks of the Government and regulating agencies needs to be examined. The strategy for industrial growth, pollution control and purposeful management of wastes and e wastes is to be optimally thought of. The points emerging here are as follows :

a. The approach of continuing industrial growth as usual or assessment of need of growth of industries friendly to waste management and reduction of wastes by addressing R's is to be cleared.
b. The approach of product suitable designing to encourage R's is addressed.
c. The development of initiatives to utilize expertise of manufacturer in managing proper disposal of e wastes for proper addressing of e waste without casting problem to environment and pollution.
d. Development of modalities for gradual shifting of burden of financial burden to the manufacturers from local agencies in terms of promotion of initiatives like Extended Producer Responsibility (EPR) or Extended Manufacturers Services (EMS) etc.
e. Development of stringent regulations for control of resources and wastes
f. Norms and standards fixation for environmental constituents and pollution levels.
g. Level and maximum permissible waste and defining wastes and fixation of life for prevention of hazards.
h. Norms for interactions of different agencies and co-ordination details
i. Enactment of regulations and acts for dealing and plugging the loopholes of existing regulations.
j. Enactment of policies for improvement or resource efficiency
k. Enhancement to extended ue and reuse of resources and waste prevention
l. Boost to recycling by extending the recycling industries and enterprises
m. Declaration of natural resource and resource prohibition for manufacturers for sustainable development for pollution and minimization of environmental degradation
n. Material efficiency to focus on viewing wastes as resource by criteriaion of employment and development of economic opportunity.
o. Material efficiency in terms of fixation of role of public and private sector , formal and informal sector for introduction of classification of wastes
p. Material efficiency for promotion of resources from collection, reuse, processing, recovery and remanufacturing.
q. Reduction of material intensity and energy intensity and dispersion of toxic substances
r. Enhancement of ability of recycling, product durability and maximization of renuable resources and reuse mindset with increase in service intensity.
s. Stress on energy efficiency by promoting business through unconventional energy sources and energy audit, combining and streamlining resource and energy efficiency policies development.
t. Encouragements to private sector for investment for energy generation as it the key factor for any type of development.
u. Creation of awareness for saving energy and using energy efficient technology for transformation.
v. Creation of proper supply chain for resource, processing, technology development and transfer, to distribution of product, meeting of environmental standards and minimization of losses by following the green technologies.
w. Development of proper code of practice for the industries and provision for broad guidelines for adherence to environmental sustainability as part of decision making for the firms and manufacturers will result in win-win conditions even for waste management.

The list and the activity are the indicators only many more segmentisation or points can be listed out. The points give a general picture of what is required in this segment only when we are dealing with the various R's for e waste management.

VI. CONCLUSION

The scenario of waste in general and e waste in particular and the threat posed by these are burning topic these days. The crunch of resources are becoming threat for the mankind The resource sharing and recovery will lead to a situation for making it available for more and more production. The shifting of technology for greener and justifiable environment and hazard free world with reusable efforts are being witnessed and increasingly becoming inevitable these days. The resources available to us are not everlasting and have some life and limitations. The conventional and sustainable e waste management with amalgamation of emerging technology will see more and more use of R's factors. The effect of R factors on the life cycle has been elaborately put in the sections. The need of regulatory and cohesiveness for tackling the situation uniformly has been identified. The does and don'ts of the Government related activities clearly indicate that the measures are far from adequate. The world needs to focus in unified manner not in the developed, developing and underdeveloped nations. The measures like donation and

shifting the products to new sections will lead to extension of life of the popular EEE products. The shifting should be done with care and routes must be through regulating agencies so that the threats of its hazardous can be viewed and minimized.

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