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Business and Economic Potential of Resource Recovery and Recycling from E-waste

(Background Paper for Parallel Roundtable 4 of the Programme)

Final Draft

This background paper has been prepared by Dr. Sunil Herat, for the Sixth Regional 3R Forum in Asia and the Pacific. The views expressed herein are those of the author only and do not necessarily reflect the views of the United Nations.

Sixth Regional 3R Forum in Asia and the Pacific

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Background Paper on

Business and Economic Potential of Resource Recovery and Recycling from E-waste

(Final)

Parallel Roundtable- 4

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Foreword

The demand for consumer electrical and electronic equipment (EEE) has been on the increase since the 1980s and a countless number of EEEs, especially computers, televisions and mobile phones, has been sold to consumers around the world. Rapid advances in technology and ready availability of newer designs at cheap prices have motivated customers to discard old EEEs even before their useful life is over. This has resulted in mountains of used EEEs, referred to as electronic waste or e-waste, to be managed by the relevant authorities. Finding a sustainable, economically viable, technically feasible and socially acceptable strategy to deal with end-of-life (EOL) management of EEEs has been not easy due to their large quantities and toxic nature.

A recent report published by the United Nations University estimated that globally 41.8 million metric tonnes of used EEEs were discarded during 2014 and this volume is expected to rise by 21% to 50 million tonnes by 2018. Growing human health concerns and environmental hazards caused by poor e-waste management are leading to the rise of e-waste management programs all over the world. Due to the urgency of addressing the immediate human health and environmental issues, most of these programs may be easily overlooking the opportunities associated with e-waste, especially at a time where resource use and depletion are also global issues. Recyclable materials in e-waste are a valuable resource which could be explored by efficient systems. The Asia-Pacific region contributes to the largest revenue share in the global e-waste management market, followed by European countries. Emerging economies in Asia Pacific such as The Republic of Korea, India, PR China and Japan are expected to be fastest growing markets for e-waste recycling. Against this background, a Position Paper has been prepared (a) to investigate the economic and business opportunities for resource recovery and recycling of e-waste in the Asia Pacific region and (b) to promote 3R as an economic opportunity towards effective management of electronic waste.

The paper covers five broad areas:

- Major challenges in e-waste management in Asia-Pacific
- Potential business and economic opportunities in e-waste
- Role of e-waste inventory, Extended Producer Responsibility (EPR), private sector and manufacturers and Public Private Partnerships (PPPs) in transforming e-waste sector into an economic industry
- Role of Research & Development (R&D) and technology transfer as key driver for harnessing economic potential for e-waste sector
- The way forward

The Paper identifies and discusses a number of issues in relation to each of these areas and presents valuable input to the policy makers in the Asia-Pacific region. This review is central in ensuring high levels of commitment from the Governments in Asia-Pacific region towards harnessing the business and economic potential of resource recovery and recycling of e-waste.

All Government representatives attending the 6th Regional Forum for Asia and Pacific are urged to contribute to their sustainable e-waste policies by reading and responding to this Position Paper.

Abbreviations and Acronyms

ADF	Advanced Disposal Fees
BFR	Brominated flame retardant
Bo2W	Best-of-2-Worlds
CPU	Central Processing Unit
CRT	Cathode ray tube
DfE	Design for environment
EACR	East African Compliant Recycling Company
EEE	Electrical and electronic equipment
EOL	End-of-life
EPR	Extended producer responsibility
ESM	Environmentally sound management
MIIT	Ministry of Industry and Information Technology
MOE	Ministry of Environment
MPPI	Basel Convention Mobile Phone Partnership Initiative
Mt	Million tonnes
NDRC	National Development and Reform Commission
NRE	Ministry of Natural Resources and the Environment
NTCRS	National Television and Computer Recycling Scheme
OECD	Organisation for Economic Co-operation and Development
OEM	Original equipment manufacturers
PACE	Basel Convention partnership for Action on Computing Equipment
PBB	Polybrominated biphenyl
PBDE	Polybrominated diphenylether
PCB	Printed circuit board
PDR	Producer Deposit-Fund
PGM	Platinum group of metals
PPP	Public private partnership
PRO	Producer responsibility organisation
R&D	Research and development
RFMB	Recycling Fund Management Board
RoHS	Restriction of Hazardous Substances
RRW	Regulated recyclable waste
SAEWA	South African E-waste Alliance
SAPO	South African Post Office
StEP	Solving the E-waste Problem
VRP	Vietnam Recycling Platform
WEEE	Waste electrical and electronic equipment

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Executive Summary

E-waste covers all items of electrical and electronic equipment (EEE) and its parts that have been discarded by the consumers. It includes almost any household or business item with circuits or electrical components using power or battery supply. E-waste is one of the fastest growing waste streams in the world today. The toxicity and resource potential of e-waste varies significantly by product, thus, making it very difficult to manage. Rapid innovation and uptake of information technology around the world coupled with the advent of new design and technology at regular intervals in the electronic sector is causing the early obsolescence of many EEE used around the world today.

During 2014 world generated around 40 million tonnes of e-waste. Improper handling of e-waste can cause harm to the environment and human health due to its toxic components. Several countries around the world are now developing policies and regulations to deal with this emerging threat. Although the current emphasise is on end-of-life management of e-waste activities such as reuse, servicing, remanufacturing, recycling and disposal, upstream reduction of e-waste generation through green design and cleaner production is gaining much attention. Recently, a perception has grown that e-waste is not only a problem but also an opportunity. E-waste can provide an alternative source of raw materials for the manufacturing industry, thus, reducing the need for extraction of natural resources and at the same time reducing the associated environmental impacts. The aim of this position paper is to investigate the business and economic potential of resource recovery and recycling from e-waste in the Asia Pacific region. The first section of the paper will describe the major barriers/challenges (policy, institution, technology) of resource recovery and recycling from e-waste in Asia-Pacific countries/cities. This section will cover e-waste generation, problems associated with e-waste, scientific studies on environmental and health impacts of e-waste and the issues and challenges of environmental sound management of e-waste.

The second section of the paper will address the potential business and economic opportunities, including market potential of resource recovery and recycling in e-waste by describing the significance of resource recovery and recycling of e-waste followed by the successful cases/business models. The third section of the paper will investigate the role of e-waste inventories, public-private sector cooperation, extended producer responsibility (EPR) in transforming the e-waste sector into an economic industry followed by examples from various countries around the world. The fourth section of the paper will investigate the role of research and development and technology transfer towards harnessing the economic potential of e-waste sector. The final section of the paper will recommend how countries can create enabling conditions to enhance the business and economic potential of resource recovery and recycling of e-waste.

The Asian region has been identified as the highest contributor to the global e-waste stream by producing 38% of the e-waste generated in 2014 with leading contributions coming from PR China, Japan and India. Most of the countries in this region are struggling to deal with the increasing e-waste generated domestically as well as imported to country from industrialised countries. Environmentally sound management (ESM) of e-waste in these countries is almost absent or very limited. Transboundary movement of e-waste is a major issue in the region. Dealing with the informal recycling sector is a complex social and environmental issue. Significant amounts of e-waste containing toxic materials can be seen dumped in open spaces and waterways. The open burning of e-waste to recover precious metals causing severe environmental and health impacts is very common. Lack of funds and investment to finance formal environmentally sound recycling infrastructures, absence of appropriate legislation to deal with the issue, tackling the informal e-waste recycling sector and achieving appropriate technology transfer are only few challenges faced by many countries. There are significant numbers of such other challenges faced by these countries in achieving ESM of e-waste.

While we are concentrating on solving the health and environmental impacts of poor e-waste management, it is easy to overlook the opportunities associated with it. E-waste contains many valuable materials such as iron, copper, aluminium and plastics and also many precious metals such as gold, silver, platinum and palladium. For example, the gold content of e-waste generated in 2014 is around 300 tonnes representing 11% of the gold mined in 2013. Unfortunately these valuable resources are lost during inefficient resource recovery and recycling practices adopted by many countries in the region.

There is an urgent need for Asia Pacific countries to develop innovative business models to incorporate the widespread informal e-waste recycling sector with the formal e-waste recycling sector to combine each other's strengths to achieve environmentally sound e-waste management. The papers describes number of examples how the informal e-waste recycling sectors in developing countries combined with original equipment manufacturers (OEMs) of EEE through their formal e-waste recycling facilities were able increase the collection and resource recovery of e-waste generated.

One of the prerequisites for harness the business and economic potential of e-waste is a proper inventory of e-waste. Unfortunately, globally, there is a lack of reliable data on generation, collection, import and export, and management schemes in general. Proper inventory will attract the investors in the e-waste recycling industry as they can clearly evaluate the resource recovery potential of valuable materials contained in e-waste.

Effective collaboration between the private and public sectors is seen as a key contributor to achieving the overall objectives of e-waste management. The ESM of e-waste cannot be achieved by public sector alone. However, these partnerships will only materialise if the enabling conditions are met for both parties. The development of fair and reasonable environmental regulations, encouragement of industry led voluntary agreements, clear definition of responsibilities of different actors in the recycling chain, OEMs given the option of treating the collected wastes in their overseas contracted treatment facilities, reasonable and fair obligations (financial and physical) for manufacturers and importers where EPR schemes exist, are few of such conditions to be met. The paper cites number of examples where successful partnerships are developed between the public and private sectors to achieve sustainable resource recovery and recycling of e-waste.

R&D plays an important role in proper resource recovery and recycling of e-waste. Adopting practices such as Design for Environment (DfE) where toxic materials in EEE are replaced with environmentally friendly raw materials can lead to increased efficiency in the recovery process. R&D can also contribute towards developing state-of-art resource recovery and recycling techniques for environmentally sound management of e-waste. However, a decision on technology transfer cannot be made purely on technology only. For example, advanced high-technology, capital intensive e-waste recycling processes adopted in highly industrialised countries may not be suitable for certain countries in the Asia Pacific region. Such technology transfer must take into account the social, institutional, political and legal aspects of a country to ensure the sustainability of the adopted technology.

The Regional 3R Forum for Asia and Pacific, through Tokyo 3R Statement, Singapore Forum on the 3Rs in Achieving a Resource Efficient Society in Asia, Ha Noi 3R Declaration on Sustainable 3R Goals for Asia and the Pacific for 2013-2023 and Surabaya Declaration on Promotion of Multilayer Partnerships and Collaboration for the Expansion of 3Rs in Asia and the Pacific, has identified and called upon the Asia and Pacific countries to develop action plans for environmentally sound management of e-waste in the region. Such action plans will also contribute towards the goals of post-2015 development agenda where we need to achieve substantial reduction in waste generation through prevention, reduction, recycling and reuse by year 2030. The issues and challenges related to e-waste must be addressed as a matter of high priority given its highest generation rate among all other waste streams.

As a way forward, all Asia and Pacific countries must develop well defined national e-waste management strategies based upon 3R concepts. Such strategy should not only address the environmental and health impacts of e-waste (end-of-pipe) but also look at the reduction of e-waste through green design (up-the-pipe). It should also create enabling conditions for relevant stakeholders to develop business and economic opportunities to recover the materials from e-waste. The strategy should also take into account the financial, institutional, political and social aspects of e-waste management, in particular, incorporation of informal e-waste recycling sector activities. Appropriate regulations and standards related to collection, storage, transport, recovery, treatment and disposal of e-waste should be a key component of this strategy. Provision of enabling conditions to develop public partnership partnerships to harness the business and economic potential of resource recovery and recycling of e-waste would ensure the sustainability (financial) of the developed strategy. Identification of organisations or institutions with potential to function as centres for excellence in developing and promoting environmental sound resource recovery and recycling practices would assist the implementation of such strategy.

1.0 Major Challenges in E-waste Management in Asia-Pacific

1.1 What is e-waste?

E-waste covers all items of electrical and electronic equipment (EEE) and its parts that have been discarded by the consumers. It is also referred to as WEEE (Waste Electrical and Electronic Equipment) or electronic waste and includes almost any household or business item with circuits or electrical components using power or battery supply. United Nations University's Solving the E-waste Problem Initiative (StEP) classifies e-waste into the following six categories[1]:

- Temperature exchange equipment (commonly referred to as, cooling and freezing equipment and could include refrigerators, freezers, air conditioners, heat pumps).
- Screens, monitors (could include televisions, monitors, laptops, notebooks, and tablets).
- Lamps (could include straight fluorescent lamps, compact fluorescent lamps, high intensity discharge lamps and LED lamps).
- Large equipment (could include washing machines, clothes dryers, dish washing machines, electric stoves, large printing machines, copying equipment and photovoltaic panels).
- Small equipment (could include vacuum cleaners, microwaves, ventilation equipment, toasters, electric kettles, electric shavers, scales, calculators, radio sets, video cameras, electrical and electronic toys, small electrical and electronic tools, small medical devices, small monitoring and control instruments).
- Small IT and telecommunication equipment (could include mobile phones, GPS, pocket calculators, routers, personal computers, printers, telephones).

1.2 How much e-waste is generated worldwide?

The generation of reliable data on the exact amount of e-waste generated in different regions of the world is difficult to achieve as the amount of used EEE reaching its end-of-life cannot be measured directly with some reliability. Most of the estimates available are based upon predictions made incorporating production or sales data, and the estimated life span of the EEE. Several countries have conducted e-waste inventories to determine the quantities and composition of e-waste. Unlike other used products, there is a tendency for consumers to store used EEE at home and in offices thus making estimation a challenging task.

One of the most recent information can be found in the Global E-waste Monitor 2014, published by the United Nations University (UNU, 2014)[1]. According to this report, the global quantity of e-waste generation in 2014 was around 41.8 million tonnes (Mt). This amount is estimated to reach 50 Mt by 2018, with an annual growth rate of 4 to 5 per cent. The study found that the Asian region produced the highest amount of e-waste (16 Mt or 38% of total), followed by Americas (11.7 Mt) and Europe (11.6 Mt). Furthermore, the study

[1] UNU (2014), The Global E-waste Monitor – Quantities, Flows and Resources, Published by United Nations University (UNU)
http://i.unu.edu/media/unu.edu/news/52624/UNU-1stGlobal-E-Waste-Monitor-2014-small.pdf

found that the top three Asia-Pacific countries with the highest e-waste generation in absolute quantities are PR China (6 Mt), Japan (2.2Mt) and India (1.7Mt).

1.3 Why e-waste is a problem?

Problems associated with e-waste are becoming well known in the scientific literature. In general, e-waste is a complicated assembly of a number of different materials, many of which are highly toxic. For example, the production of semiconductors, printed circuit boards, disc drives and monitors used in computer manufacturing utilises many hazardous chemicals. Computer central processing units (CPU) contain heavy metals, such as cadmium, lead and mercury. Printed circuit boards (PCB) contain heavy metals, such as antimony, silver, chromium, zinc, lead, tin and copper. Lead (Pb) is used in cathode ray tubes (CRTs) in monitors, tin–lead solders, cabling, PCBs and fluorescent tubes.

E-waste also contains brominated flame retardants (BFRs), such as polybrominated biphenyls (PBB) and polybrominated diphenylethers (PBDEs), which are used in PCBs, connectors, covers and cables. There is a growing body of literature suggesting that BFRs have negative environmental and health effects, and, hence, should be limited or replaced altogether. Exposure to PBDEs of personnel working in e-waste recycling facilities and of people in surrounding areas has been studied by researchers worldwide.

1.4 Scientific studies on environmental and health impacts of e-waste

The environmental and health impacts of e-waste is thoroughly investigated by the global research community, In particular, there is significant interest on the environmental and health impacts of e-waste recycling in informal sector. Song and Li (2014a, b)[2] [3] undertook a detailed systematic review of both environmental and human impacts of informal waste recycling in PR China. Findings of their studies are summarised below:

Human impacts

This study investigated the recent studies on human exposure to e-waste in PR China, with particular focus on exposure routes (e.g. dietary intake, inhalation, and soil/dust ingestion) and human body burden markers (e.g. placenta, umbilical cord blood, breast milk, blood, hair, and urine) and assesses the evidence for the association between such e-waste exposure and the human body burden in PR China. The results suggested that residents in the e-waste exposure areas, located mainly in the three traditional e-waste recycling sites (Taizhou, Guiyu, and Qingyuan), are faced with a potential higher daily intake of these pollutants than residents in the control areas, especially via food ingestion. Moreover, pollutants (PBBs, PBDEs, PCBs, PCDD/Fs, and heavy metals) from the e-waste recycling processes were all detectable in the tissue samples at high levels, showing that they had entered residents' bodies through the environment and dietary exposure[4].

Environmental effects

[2] Song, Q. and Li, J. (2014a) A systematic review of the human body burden of e-waste exposure in China, *Environment International*, 68, 82-93

[3] Song, Q. and Li, J. (2014b) Environmental effects of heavy metals derived from e-waste recycling in China: A systematic review, *Waste Management*, 34, 2587-2594

[4] Song, Q. and Li, J. (2014a) A systematic review of the human body burden of e-waste exposure in China, *Environment International*, 68, 82-93

This study investigated the reviews recent studies on environmental effects of heavy metals from the e-waste recycling sites in PR China, especially Taizhou, Guiyu, and Longtang. The intensive uncontrolled processing of e-waste in PR China has resulted in the release of large amounts of heavy metals in the local environment, and caused high concentrations of metals to be present in the surrounding air, dust, soils, sediments and plants. Though the pollution of many heavy metals was investigated in the relevant researches, the four kinds of heavy metals (Cu, Pb, Cd and Cr) from e-waste recycling processes attracted more attention. The exceedance of various national and international standards imposed negative effects to the environment, which made the local residents face with the serious heavy metal exposure.[5]

A summary of number of scientist studies undertaken to evaluate the health and environmental impacts of e-waste management in Asia-Pacific region could be found in (Herat and Agamuthu, 2012)[6].

1.5 Policies, Issues and challenges of environmentally sound management of e-waste

Some Policy Approaches in Asia-Pacific Region

Japan

The Japanese government has introduced three laws to address the e-waste issue.
The *Specific Household Appliance Act* (1998), also known as the Home Appliance Recycling Law, requires the consumers to pay a recycling fee to contribute towards the disposal of e-waste. This law only applies to larger items such as televisions, refrigerators, air conditioners and washing machines. The *Promotion of Recycling of Small Waste Electrical and Electronic Equipment Act* (2013) extends the coverage to small items such as digital cameras, mobile phones, computers and printers and game console. Unlike with larger items, the consumers are not required to pay a recycling fee for small items as the materials recovered from these devices comprise of valuable materials for e-waste recyclers. The third law, *Law for the Promotion of Effective Utilisation of Resources* (2001), commonly known as Recycling Promotion Law, encourages manufacturers to recycle the goods voluntarily and reduce the generation of e-waste. The main objective of this Act is to promote concepts such as design for environment to facilitate waste reduction, recycling and reuse.

An amendment to the Law for the Effective Utilisation of Resources took place on 1 July 2006 when the Japanese version of the RoHS (also known as J-Moss or JIS C 0950) was introduced. This amendment mandates that manufacturers provide material content declarations for certain categories of electronic products from sold after 1 July 2006. Manufacturers and importers are required to label their products and provide information on the six EU RoHS substances: lead, mercury, chromium VI, cadmium, PBB and PBDE. Apart from manufacturers, importers of the items listed above must meet the Design for Environment (DfE) criteria, which are required for domestic manufacturers.

PR China

[5] Song, Q. and Li, J. (2014b) Environmental effects of heavy metals derived from e-waste recycling in China: A systematic review, *Waste Management*, 34, 2587-2594

[6] Herat, S. and Agamuthu, P. (2012) E-waste: a problem or an opportunity? Review of issues, challenges and solutions in Asian countries, *Waste Management & Research*, 30, 11, 1113-1129

PR China is considered to be one of the fastest growing economies in the world the largest exporter of information and communication technology products to the world surpassing Japan, European Union and United States.

PR China's problem with e-waste has come about mainly due to recycling operations conducted by labour intensive small and informal business sectors which lack the capacity to handle such wastes in a proper manner. The application of primitive technology to recover only the valuable metals while disposing other heavy metals and toxic chemicals and low awareness of health and environmental aspects have all led to deterioration of the problem.

The current legal framework in PR China lacks a clear prescription to manage the e-waste stream. At present governments at different level pay attention to the problems caused by e-waste. There are three laws in PR China which are relevant to e-waste management: *Circular Economy Promotion Law, Solid Waste Pollution Control Law* and *Clean Production Promotion Law.* These laws do not have direct stipulations, but provide a legal framework for managing e-waste in PR China. Based on the above laws, four government agencies involved in e-waste management have released various administrative regulations to cover different aspects of e-waste management including e-waste collection, treatment and financing.

The National Development and Reform Commission (NDRC), an agency responsible for resource efficiency and environmental protection in 2004 raised a policy entitled "*Management of Recycling Home Appliances and Electronic Equipment*" The aim of this policy is to increase resource efficiency from e-waste management. In 2007, the Ministry of Environment Protection (MEP) issues "*E-waste Pollution Prevention Management Measure*" with the aim to prevent environmental pollution caused by e-waste dismantling, reuse and disposal. In 2006, the Ministry of Industry and Information Technology (MIIT), issues an administrative rule entitled "*Pollution Prevention and Management of IT Products*". This rule aims to prevent the use of hazardous substances during the production, the Chinese equivalent to European Union's RoHS (Restriction of Hazardous Substances). Also in 2011, the State Council issues a regulation on "*Recycling and Disposal of Waste Electrical and Electronic Equipment*" which proposed the implementation of EPR. Although PR China has established a legal system for managing e-waste, current regulations lack an integral effort as each regulation covers a specific aspect of e-waste management.

India

In India, e-waste is a major issue due to the generation of domestic e-waste as well as imports from developed countries. India's electronic industry is one of the fastest growing industries in the world. The formal e-waste recycling sector in India is currently being developed in major cities. However, informal recycling operations have been in place for a long time in India with over 1 million poor people in India being involved in the manual recycling operations. Most of these people have very low literacy levels with little awareness of dangers of the operations. Severe health impacts and environmental damage are wide spread in India due to e-waste processing by the informal sector.

In 2005, India's Central Pollution Control Board developed guidelines for environmentally sound management of e-waste in India. E-waste in India is not regulated at the present time. However, the Ministry of Environment and Forest as part of the Environmental Protection Act of India has enacted the 'E-waste (Management and Handling) Rule of 2011 to take effect from 1st May 2012. The rule mandates producers to be responsible for the collection and financing the systems according to extended producer responsibility concept. The rule clearly defines the responsibilities of the producer, collection centres, consumer or bulk consumers, dismantlers and recyclers.

Bangladesh

Bangladesh has no specific laws or ordinances related to e-waste management. The National Environmental Policy was adopted in 1992, The Environmental Conservation Act in 1995 and Medical Waste Management Rules in 2008. The Government of Bangladesh has given top priority to the preparation of 'Electrical and Electronic Waste (Management and Handling) Rules' in 2011. In addition, the Government has already prepared a National 3R (Reduce, Reuse and Recycle) Strategy incorporating some aspects of e-waste management. Furthermore, two Rules, the Hazardous Waste Management Rule (under preparation) and the draft Solid Waste Management Rule (prepared and in the consultation stage) could also accommodate the issues related to e-waste.

Pakistan

Pakistan currently has no inventory or exact data on e-waste generation. Pakistan has no regulations specifically targeting e-waste although the National Environment Policy has been active since 2005. The Ministry of Environment overseas the environmental protection and movement of chemicals and waste. There is no formal mechanism to manage e-waste at national level. Therefore, people use different methods to manage e-waste locally. Informal recycling sector is very active where a number of workers, including children, earn their living my dismantling the electronic scrap and extracting valuable metals. Open burning and open dumping of e-waste is very common in Pakistan.

Thailand

Thailand suffers from issues such as lack of general awareness about e-waste, incomplete databases and inventories related to e-waste, lack of environmental sound management practices and lack of specific laws and regulations on e-waste. In order to address these issues the Thailand Government passed the National Strategic Plan on Integrated Management of E-waste in July 2007. The strategy provides a platform for the work related to the management of e-waste in various ministries to ensure that the following five objectives are met:

- To manage domestic post-consumer e-waste in a scientific and systematic manner;
- To establish an efficient and sustainable e-waste management system with cooperation from every sector of society;
- To reduce hazardous wastes from e-waste at the origin and to encourage environmentally friendly design and production;
- To enhance the competitiveness and negotiation power of the country in international trade; and,
- To have nationwide efficient and effective integrated e-waste management by 2017

The legal aspect of the above plan is the draft Act on Economic Policy Instruments for Environmental Management which will combine all the economic instruments including pollution tax, emission charge and product fee under one law. The draft Act allows products to be charged a certain fee for the management of end-of-life products. The Act also proposes a ‘Buy-back’ for consumers through government subsidized Buy-back Centers to create a market for used products containing hazardous substances. These Buy-back Centers are also responsible for delivering the used products to authorized recyclers. A new fund called the ‘Environmental Taxes and Fees Fund’ funded through the product fees will cover the subsidies of Buy-back centers.

Vietnam

As with many other developing countries one of the main issues related to e-waste in Vietnam is the informal recycling activities being undertaken in Vietnamese craft villages where open burning of e-waste, sub-standard recycling of circuit boards and open dumping of residues from recycling is taking place. These activities are undertaken by workers, farmers and women without proper safeguards. E-waste generated due to transboundary movements is a major issue in Vietnam where conflict occur between the benefits of using second hand electronic goods versus cost of waste management and pollution control due to improper e-waste recycling. The issue is compounded by the difficulties with clear criteria distinguishing between second hand goods and e-waste. Furthermore, there is no local capacity to deal with the recycling of all the materials in e-waste using best available technology. There is an urgent need in Vietnam to develop specific legislation related to e-waste incorporating reduce, reuse and recycling (3R) strategy where the responsibilities of various stakeholders are clearly defined.

In August 2013, the Prime Minister of Vietnam signed the Decision No. 50/2013/QD-TTg which requires the enterprises manufacturing or importing electrical and electronic products to be responsible for collection, transport and processing of e-waste. The Vietnamese Ministry of Natural Resources and Environment recently proposed detailed specifications on e-waste take scheme which includes provisions on the recovery, transportation, treatment and reporting.

Malaysia

E-waste has been regulated in Malaysia since 2005. The Department of Environment (DOE) within the Ministry of Natural Resources and the Environment (NRE) is responsible for the planning and enforcement of regulatory requirements related to e-waste. Although there are no direct regulations to deal with e-waste, the management of e-waste is incorporated within the Environmental Quality (Scheduled Waste) Regulations 2005 and the Environmental Quality (Prescribed Premises) (Treatment, Disposal Facilities for Scheduled Waste) Regulations, 1989 (control on collection, treatment, recycling and disposal of scheduled waste including e-waste). In January 2008, the Department of Environment (DOE) issued the ‘Guidelines for Classification of Used Electrical and Electronic Equipment in Malaysia’ for assisting all stakeholders involved in e-waste management to identify and classify the used products according to the regulatory codes. The guideline provides a list of the types of electrical and electronic waste which may contain the hazardous compounds or materials.

E-waste generated from industries in Malaysia can send their e-waste to the recovery facilities licenced by the DOE. These facilities comprise of full recovery facilities as well as partial recovery facilities and built and operated by private companies. These e-waste recovery facilities pay the industries or e-waste generators when they obtain the supply of e-wastes. It is reported that public also can now send their e-wastes, limited to used mobile phones, mobile phone’s batteries and their accessories, computers and their accessories, as well as television sets to the e-waste collection centres managed by the local authorities Malaysia does not allow the importation of hazardous waste including e-waste into the country. However, it allows importation of used electronic and electrical equipment into country for direct reuse, provided such equipment shall not be more than three years from the date of its manufacture. The current voluntary take back scheme of e-wastes has not been implemented widely by the producers or importers, hence a compulsory requirement of take back scheme through legislation is required to increase the collection rates.

Issues and Challenges

The issue of environmentally sound management of e-waste is a global problem arising from transboundary movement among all countries and regions, and thus requires global solutions. Large amounts of e-waste are currently being exported to developing countries for the purpose of reuse, refurbishment, recycling and recovery of precious materials. Today India, PR China, The Philippines, Hong Kong SAR of China, Indonesia, Sri Lanka, Pakistan, Bangladesh, Malaysia, Vietnam and Nigeria are among the most favoured nations for exporting e-waste. However, many recycling and recovery facilities in these countries operate in an environmentally unsound manner causing significant environmental and health impacts.

Significant amounts of e-waste containing hazardous materials can be seen dumped in open-land and waterways. The major environmental and health impacts occur during open burning of e-waste to recover precious metals. In spite of these significant environmental and health impacts, recycling and recovery operations have generated a huge informal employment sector in these countries. In addition to receiving e-waste from developed countries, developing countries are also emerging as significant generators of e-waste themselves.

Another major issue faced by developing countries in dealing with e-waste is how to tackle the emerging informal e-waste recycling sector. In most developing countries formal recycling of e-waste using best practice technologies in modern recycling facilities is rare. As a result, most of the e-waste is managed using various improper methods, such as open dumps, backyard recycling and disposal into surface water bodies. It is common to see open burning of plastics to reduce e-waste volumes, copper wires to salvage valuable metals and acid leaching to recover precious metals from PCBs.

One of the main problems faced by developing countries is the lack of funds and investment to finance formal recycling infrastructures, and the absence of appropriate legislation to deal with the issue. EPR is seen globally as one of the most effective ways of dealing with the e-waste issue. However, unlike in the developed world, implementing EPR in developing countries is a major challenge for policy makers. For example, it’s a major challenge for the government to collect funds from producers or imports if the goods are smuggled into the country, or if the small, shop-assembled products have a large share of the market. The competition between the formal and informal recycling sectors to gain access to e-waste is also a major problem.

Following are some of the major issues and challenges for ESM of e-waste in developing countries:

- Increasing volume of e-waste imported illegally into developing countries in the name of second-hand EEE, most of which are nearing their end-of-life and hence become e-waste in very short time

- Accessing funds and investment to finance proper e-waste recycling facilities
- Developing appropriate policies and legislation specifically to deal with e-waste
- Implementing mandatory or effective voluntary take-back schemes, such as EPR
- Ability to gather data and inventory on e-waste generation including transboundary movements
- Establishment of proper infrastructure for e-waste collection, transportation, storage, treatment, recovery and disposal
- Improving the working conditions and minimisation of work-related hazardous exposure at e-waste management facilities
- Raising awareness of health and environmental impacts of e-waste
- Adoption of green product design practices by equipment manufacturers
- Development of pool of experts and resources to deal with the e-waste issues
- Development of public-private partnerships to implement e-waste resource recovery and recycling operations

Cooperation among the key stakeholders is the key to finding solutions to the above issues and challenges. Although currently there are number of activities conducted by various countries and donor agencies, harmonisation of these activities is needed to maximise the limited resources.

As seen from above there are numerous challenges to overcome before the developing countries achieve ESM of e-waste. Number of workshops and studies has been conducted by organisations such as Basel Convention to investigate the obstacles in developing countries to adopt ESM of e-waste. These have identified lack of e-waste inventories, lack of trained personnel to enforce ESM practices, lack of legislation including export and import rules, inadequate infrastructure to collect, handle, recycle and recover materials from e-waste and lack of awareness about the health and environmental impacts of unsound e-waste management practices as the main obstacles in achieving ESM of e-waste.

Informal sector

To manage the emerging threat from e-waste, and due to the urgency of the issue, number of developing countries are looking into adopt policies and technologies that are already been implemented in developed countries where proper infrastructure is in place to manage e-waste. However, the economic, environmental and social situation in number of these developing countries (mainly located in Asia and Africa) are different to the developed world, hence, the need for adapting, implementing, and scaling up appropriate technologies that are more suited to the local conditions. One of the key areas that developing countries need to concentrate relates to how to deal with the informal e-waste recycling sector. It is important to note here that in many developing countries the informal sector is very active in activities related to the e-waste recycling chain. These informal recyclers are motivated by the precious materials contained in the e-waste stream and its market value. In countries such as India and PR China, where significant amount of e-waste recycling is taking place, informal collectors achieve very high collection efficiencies. In fact, informal collection of e-waste does not have any major adverse impacts on the environment. Instead they lead to high collection rates and many economic and social benefits to the poor section of the community. The informal sector is also involved in the second stage of the e-waste recycling chain - dismantling pre-processing. Even here there are no major impacts on the environment instead more economic and social benefits to poor community. The last stage of the e-waste recycling chain where processes/techniques are necessary to extract the valuable components such as metals is where the current environmental impacts are. Most of the informal recyclers utilise low efficiency processes resulting in major health and environmental impacts. For example primitive technologies utilised by informal recyclers to extract raw materials from printed wire boards, wires and other metal bearing components have very low material recovery rates and also result in major environmental impacts. The challenge for the policy makers in developing countries is how to achieve efficiencies in the informal sector at the same time taking into account the environmental and social aspects of their operations.

Prohibiting and imposing fines on informal recycling have not helped in countries like PR China and India. This is due to the fact that informal recycling is undertaken by the poor people and as such the government is unable to impose heavy fines as they cannot pay it. These governments then tried to regulate the informal e-waste recycling sector by licensing them. However, the effectiveness of such a scheme depends a lot on the responsibility of the disposer of e-waste. The challenge is how to deal with the e-waste disposer who receives more money from unlicensed informal recyclers than from the licensed recyclers. The emergence and growth of the informal sector in developing countries is the result of intricate interactions between economic incentives, regulation gaps, industrial interdependence and the social reality and it can be argued that informal sector may remain an influential recycling force for years to come. The whole informal recycling chain must be thoroughly investigated on which steps are environmentally harmless and should remain and which steps of the material mass flow should be changed for better downstream environmental and recycling performance.

2.0 Potential Business and Economic Opportunities in E-waste

2.1Significance of resource recovery and recycling of e-waste

The use of natural resources in production and consumption has significant impacts on the environment. The processes associated with extraction, processing, transport, use and disposal of materials contribute towards the deterioration of the environment and ecosystems. Recent decades have experienced significant growth in demand for raw materials worldwide mainly driven by the high levels of material consumption in developed countries and rapid industrialisation of emerging economies. According to OECD, the amount of materials extracted, harvested and consumed worldwide increased by 60% since 1980, reaching close to 62 billion metric tonnes in 2008 and expected to reach 100 billion tonnes by 2030. Over the last 30 years, the strongest growth in raw materials demand has been for metal ores. The global metal extraction has more than doubled between 1980 and 2008, increasing from 3.5 billion tonnes to 8.2 billion tonnes or by 133%. [7]

Resource use efficiency which refers to the effectiveness with which an economy uses materials extracted from natural resources to generate economic value is central to green growth. Last two decades have seen a significant increase in waste generation in line with growing consumption of material resources in many countries. As a result, many valuable natural resources are disposed of as waste and are lost to the economy. OECD estimates that about a fifth of materials extracted worldwide ends up as waste. This amounts to over 12 billion tonnes of natural resources lost per year. This is alarming considering the facts that

[7] OECD (2013), Material Resources, Productivity and The Environment: Key Findings http://www.oecd.org/greengrowth/MATERIAL%20RESOURCES,%20PRODUCTIVITY%20AND%20THE%20ENVIRONMENT_key%20findings.pdf

environmental pressures occur not only at the extraction stage of the material consumed but also at the disposal stage.

OCED has noted that recycling rates have increased worldwide for many important materials such as glass, steel, aluminium, paper and glass, with some reaching very high levels. However, recycling activities remain very low for many precious metals, which is a major concern given that these metals are central to number of modern day consumer items.

Although e-waste is usually regarded as a problem due to its environmental damage it is causing if not properly dealt with in an appropriate way, it is easy to overlook the opportunities associated with e-waste, especially at a time where resource use and depletion is also a global issues. Strictly speaking, it can be argued that the problem with e-waste is not due to the materials that are contained in them but due to the inappropriate ways that they are dealt with at the end-of-life. EEE manufacturing consumes many precious metals and therefore an important resource for the world's demand for metals. Some refer to e-waste as a 'above ground mine" ready to be harvested. They argue that mining of used EEE to recover the metals contained in them needs only a fraction of energy required to mine them from natural ores. E-waste contains many valuable materials such as iron, copper, aluminium and plastics and also many precious metals such as gold, silver, platinum and palladium. Table 1 illustrates the important metals used for EEE.

Metal	Primary production*	By-product from	Demand for EEE	Demand/ production	Price**	Value in EEE**	Main applications
	t/y		t/y	%	USD/ kg	10^6 USD	
Ag	20 000	(Pb, Zn)	6 000	30	430	2.6	Contacts, switches, solders…
Au	2 500	(Cu)	300	12	22 280	6.7	Bonding wire, contacts, integrated circuits…
Pd	230	PGM	33	14	11 413	0.4	Multilayer capacitors, connectors
Pt	210	PGM	13	6	41 957	0.5	Hard disk, thermocouple, fuel cell
Ru	32	PGM	27	84	18 647	0.5	Hard disk, plasma displays
Cu	15 000 000		4 500 000	30	7	32.1	Cable, wire, connector…
Sn	275 000		90 000	33	15	1.3	Solders
Sb	130 000		65 000	50	6	0.4	Flame retardant, CRT glass
Co	58 000	(Ni, Cu)	11 000	19	62	0.7	Rechargeable batteries
Bi	5 600	Pb, W, Zn	900	16	31	0.03	Solders, capacitor, heat sink…
Se	1 400	Cu	240	17	72	0.02	Electro-optic, copier, solar cell
In	480	Zn, Pb	380	79	682	0.3	LCD glass, solder, semiconductor
Total			**4 670 000**			**45.4**	

Table 1: Important metals used for electric and electronic equipment (based on demand in 2006). [8]

A compressive study undertaken by the United Nations Environment Program and United Nations University [9] have revealed the following facts about the resource availability from e-waste:

[8] UNEP and UNU (2009a), Sustainable Innovation and Technology Transfer Industrial Sector Studies: Recycling – From E-Waste to Resources, Published jointly by UNEP and United Nations University (UNU) http://www.unep.org/PDF/PressReleases/E-Waste_publication_screen_FINALVERSION-sml.pdf

[9] UNEP and UNU (2009a), Sustainable Innovation and Technology Transfer Industrial Sector Studies: Recycling – From E-Waste to Resources, Published jointly by UNEP and United Nations University (UNU)

- Mobile phone contains about 40 base metals including copper (Cu), tin (Sn), cobalt (Co), indium (In) and antimony (Sb) and precious metals such as silver (Ag), gold (Au) and palladium (Pd) representing around 23% of the weight of the phone. It is estimated that one tonne of phone handsets (without battery) would contain 3.5kg of Ag, 340 g Au, 140g of Pd and 130 kg of Cu. This is very significant considering that global demand for mobile phones is over 1 billion.

- Electronics make up 80% of the world demand for indium (magnetic properties in hard disks), 50% of antimony (flame retardants), 30% of silver (contact, solders), 12% of gold (circuits), 14% of palladium (capacitors), 30% of copper (wires) and 15% of tin (solders).

- E-waste generated globally in 2007 from mobile phones and computers alone would have contributed to 3% of the world mine supply of gold and silver, to 13% of palladium and 15% of cobalt.

Global Waste Monitor 2014 (UNU, 2014) reports that the gold content of total e-waste generated in 2014 is roughly 300 tonnes, which represents 11% of the global gold production from mines in 2013.

2.2 Issues related to resource recovery and recycling of e-waste

Although the resource value of materials such as metals in EEE are well known and availability of technologies to recover these materials are increasing becoming available, only a fraction of e-waste is currently recycled even in developed countries. There are number of reasons why this is the case. Firstly, end-of-life EEE does not reach the recycling process as part of the EEE is stored at home. Secondly, of the collected e-waste, a part is sent directly to recycling for environmentally sound recovery of materials while the rest is reused and then recycled or exported for reuse in developing countries where environmentally sound recycling facilities rarely exist.

Even in environmentally sound recycling facilities materials can be lost in the process as it is not possible recover 100% of the materials. However, rudimentary recycling processes employed in developing and transition economies achieve far less recovery yields especially with valuable metals. These practices employ substandard treatment techniques including open burning to extract precious metals and cyanide leaching to recover metals such as copper, gold and silver. The discharge from these facilities included highly contaminated water and toxic gaseous emissions. Valuable metals are lost due to the inefficiency of the system. Whereas an advanced integrated smelter could recover over 95% of the gold, recycling practices in developing countries could achieve only around 25%.

2.3 Case study: Recovery of scares and valuable metals from e-waste [10]

E-waste recycling at Umicore's integrated metals smelter at Hoboken/Antwerp, Belgium

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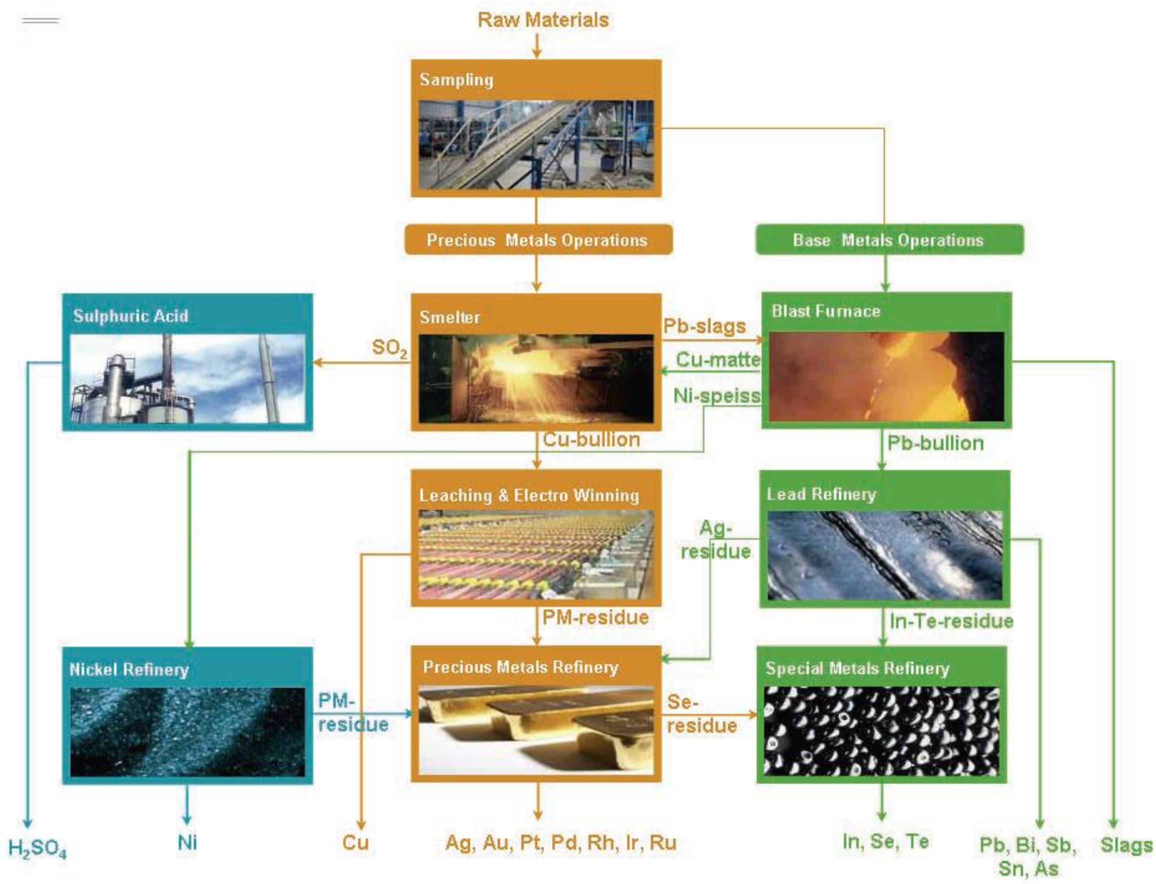
http://www.unep.org/PDF/PressReleases/E-Waste_publication_screen_FINALVERSION-sml.pdf

[10] UNEP and UNU (2009b), Sustainable Innovation and Technology Transfer Industrial Sector Studies: Critical Metals for Future Sustainable Technologies and Their Recycling Potential, Published jointly by UNEP and United Nations University (UNU) http://www.unep.fr/scp/publications/details.asp?id=DTI/1202/PA

This case study is an overview about Umicore's integrated metals smelter and associated metals separation units at Hoboken/Antwerp in Belgium.This plant with a clear focus on end-of-life materials and by-products is able to recover 17 different metals; Au (gold), Ag (silver), Pd (palladium), Pt (platinum), Rh (rhodium), Ir (Iridium), Ru (Ruthenium), Cu (Copper), Pb (lead), Ni (nickel), Sn (tin), Bi (bismuth), Se (selenium), Te (tellurium), Sb (antimony, As (arsenic) and In (indium).Typical end-of-life products as input in Hoboken are e-scrap, spent industrial catalysts, spent automotive catalysts etc. The plant has an input capacity of about 350,000 tons. Umicore announces the following yearly output capacities for the bulk metals lead (125,000 t), copper (30,000 t), nickel (2,000 t), tin (1,000 t), antimony (3,000 t) and for the special and precious metals silver (2,400 t), gold (100 t), platinum (18 t), palladium (24 t), rhodium (5 t), bismuth (400 t), indium (50 t), tellurium (150 t), selenium (600 t).

In the flow sheet below the material flows and main process units around Umicore's integrated smelter are performed. After sampling and (depending on the end-of-life material) pre-treatment operations the input materials are transferred into the large smelter. Plastic components (circuit boards) are used as reducing agents and fuel substitutes. The obtained copper bullion (copper has the function of a so-called collector-metal) is transferred into a leaching and electro-winning process to separate copper from the precious metals. The precious metals are separated from themselves and purified in the precious metals refinery by complex hydro-metallurgical operations. Silver, gold, platinum, palladium, rhodium, ruthenium and iridium are recovered in this operation unit and get ready for the use in jewellery, automotive and industrial catalysts, electronic industry etc.

The lead slag phase (lead worked as collector metal for special metals) is transferred from the smelter into a special blast furnace. In this process unit, lead bullion is separated from a copper matte phase (back into integrated smelter) and a nickel speiss phase. From the last one, nickel is recovered in the nickel refinery (separated precious metals are transferred into the precious metals refinery). The lead bullion, which contains silver, indium, tellurium, selenium, bismuth, antimony, arsenic and tin is purified via different steps to lead and the eight different other metals are separated as high purity metals.



2.4 Successful cases/business models

(1) Case Study
Dell Reconnet [11]

Dell has made it easy to recycle used computer equipment through Dell Reconnect, a partnership with Goodwill Industries. Goodwill Industries is an American non-profit organization that provides job training, employment placement services, and other community-based programs for people who have disabilities. Customers can take old computer equipment of any brand, in any condition, to one of Goodwill's 2,000+ participating locations throughout North America and they make sure the system and accessories are refurbished or recycled responsibly. Some systems in working condition are refurbished and resold through Goodwill, creating green jobs to further support Goodwill's mission of helping people with disabilities and disadvantages by providing education, training and career services. In addition, this program allows Goodwill customers to purchase modern technology at an affordable cost. Whatever parts cannot be reused or refurbished are broken down securely and recycled responsibly, meeting Dell's extensive and strict Electronic Disposition Policy. Dell ensures that no environmentally sensitive materials will be sent to landfills and no items will be exported to developing countries.

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[11] http://www.dell.com/learn/us/en/uscorp1/corp-comm/us-goodwill-reconnect

Dell is working in many developing countries to discarded electronics are not seen as waste but rather a valuable resource and an opportunity to earn income. Moving from an informal recycling culture to a formal model in Kenya required a combination of strong legislation, infrastructure development for collection and treatment, material and safety training for workers, and public education.

Camara is an international charity and social enterprise that uses technology to deliver 21st century skills, and as such improve education in disadvantaged communities around the world. Camara partnered with Dell and the EACR (East African Compliant Recycling Company) to set up the first Camara / Dell / EACR Collection Point for e-Waste in Mombasa, Kenya.

A team of collectors from Camara will source and collect e-waste in all shapes and sizes from businesses and schools as well as private individuals, with a focus on computers and monitors. A container fitted with weighing scales is used to receive the e-waste so that collectors can be paid fairly for what they bring in. The next step is disassembling equipment so that materials can be broken down into smaller parts or fractions until the point when the container is full and ready to be collected by the EACR. Each container collected is replaced with an empty container, and the process continues. Camara aims to dispatch as many as one container of e-waste per week going forward, an ambitious but achievable target. The revenue from e-wasted material is reinvested into the program.

(2) Case Study
The South African Post Office (SAPO) and Cisco Takeback and Recycle Programme [12]

The South African Post Office (SAPO) faced a common dilemma shared by many organisations when their networking equipment becomes obsolete: How do you dispose of the outdated equipment in a safe, cost-effective way that doesn't damage the environment or your operating budget? Through Cisco's innovative Takeback and Recycle programme, SAPO and its technology integrator, Dimension Data, were able to painlessly and effectively solve its outdated equipment problem by identifying and de-installing all targeted equipment, and ship it back to the UK for Cisco to process through its world-leading recycling programme, reclaiming over 99% of the materials in the equipment for use in the manufacture of new devices.

SAPO is a massive nation-wide business. It delivers to an area of more than 1.2 million square kilometres, through more than 2,000 outlets and 5,500 service points. It is the largest business undertaking in the country.

SAPO had a large amount of hardware and other networking equipment that had reached end of life and been replaced by newer, more updated hardware with greater functionality. This equipment was temporarily held at its Pretoria Central facility. SAPO now faced the responsibility of disposing of this equipment in the best way possible.

SAPO approached Dimension Data to find a way to dispose of its outdated inventory. Dimension Data teamed up with Cisco to investigate a possible solution including local disposal through a waste company. The major stumbling block was that to date, there is no

[12] http://www.dimensiondata.com/en-ME/Downloadable%20Documents/SA%20Post%20Office%20Case%20Study.pdf

recycling plant in South Africa that meets the stringent policy guidelines that Cisco has for recycling.

Dimension Data provides SAPO with networking equipment that enables the effective transfer of data between post office branches and the head office. Dimension Data and Cisco have a rich collaborative history that stretches back over a decade. Cisco and Dimension Data were able to provide a complete solution for SAPO's dilemma through Cisco's innovative Takeback and Recycle programme. This programme reduces customer costs associated with tracking, storing and managing obsolete Cisco networking and IT assets. The programme provides a channel through which customers can contact Cisco. Cisco will then collect all Cisco-branded equipment and dispose of it in an environmentally safe manner, using high end processes that comply with all current E-Waste regulations.

SAPO and Dimension Data followed an easy three step process to access the benefits of the programme. The first step was to identify all the equipment SAPO wanted to return to Cisco. Thereafter, the equipment that had been identified was de-installed and packed on 13 pallets. The final step was to contact Cisco to arrange for pickup. Thereafter, the Takeback and Recycle programme machinery went into action to ship the equipment back to the UK, where it was appropriately handled.

(3) Case Study
Ericsson E-waste Take Back Programs [13]

MTN Benin (a telecom company), has partnered with Ericsson under their Ecology Management Program, to launch the first electrical and electronic equipment waste (e waste) collection and awareness drive in Benin. This campaign is geared towards creating awareness and minimizing the potential environmental impact associated with the disposal of decommissioned electrical and electronic equipment in the country. Africa, particularly West Africa, is one of the more highly affected continents because large quantities of end of life materials from around the world end up at dumps in this region. This project provides a sound platform for raising awareness and discussing these issues.

A collection depot with a container has been opened at Stade de l'Amitié de Kouhounou, Cotonou, Benin. This will be operational for one month with the invitation to the general public to seize the opportunity to properly dispose of all forms of electronic waste. Leading the way, MTN will dispose of all electronic waste including old equipment purchased from Ericsson. At the close of the campaign, collected e-waste is transported to an Ericsson-approved recycling partner in Durban, South Africa for environmentally sound e-waste recycling and resource recovery.

Ericsson has developed a similar take back scheme in Ghana with Airtel, leading mobile operator. Under this scheme e-waste is loaded at Airtel Ghana's warehouse facilities and then transported by sea to the Ericsson approved recycling partner in Durban, South Africa. There, the sorting and dismantling process is initiated before being shipped to the partner's main recycling facility in Netherlands for final recycling and resource recovery.

(4) Case Study

[13] http://www.ericsson.com/news/1887986

Australia's MobilMuster Program for Used Mobile Phones [14]

MobileMuster is the mobile phone industry's official product stewardship program in Australia. It is a not-for-profit program voluntarily funded by Nokia, Motorola, Samsung Electronics, HTC, Huawei, ZTE, Force Technology, Telstra, Optus, Vodafone and Virgin Mobile. MobileMuster's promise is to keep old mobiles out of landfill and recycle them in a safe, secure and ethical way. It is a free service and accepts all brands of handsets, batteries, chargers and accessories. No mobile phones are refurbished and sold for reuse

There are over 30 million mobile phone services in Australia as at June 2012. Australians upgrade or exchange their mobile phones every 18 to 24 months. MobileMuster has over 4,000 free public drop off points across Australia, including mobile phone retailers Telstra, Optus, Vodafone, Virgin Mobile, Fone Zone, Allphones, Dick Smith as well as participating local councils, Officeworks and Battery World stores. Customers can also post in their old mobiles using a free reply paid recycling satchel available from Australia Post outlets.

In 2012/2013 MobileMuster collected 87 tonnes of mobile phone components including an estimated1 million handsets and batteries and 38,479kg of accessories. This represents a collection rate of 53% of available mobile phones. Since the program started in November 1998, 1,014 tonnes of mobile phone components have been collected and recycled as at 30 June 2013. This includes 7.791 million batteries and handsets plus more than 518,000 kg of accessories. The recycling of collected items go through a 6 stage process below:

Step 1 (Sorting): First, phones are dismantled and sorted into the following components: batteries (NiCad, NiMetHyd, Lithium Ion), printed circuit boards, handsets, chargers/accessories, plastics, metals and paper/cardboard packaging.
Step 2 (Batteries): Batteries are sorted into their chemical types. All lithium ion and nickel metal hydride (NiMetHyd) batteries are shipped to TES-AMM in Singapore where they're processed for cobalt, lithium and nickel. All Nickel cadmium (NiCad) batteries are shipped to KOBAR Ltd in The Republic of Korea where they are processed for nickel (to make stainless steel), cadmium (to make new batteries) and copper.
Step 3 (Circuits): Circuit boards are stored and then shipped to TES-AMM in Singapore where they are processed for precious metals including gold, silver, copper and lead.
Step 4 (Casings): Pure plastic handset casings with are sent to local plastics manufacturers Australian Composite Technology, who shreds and uses the plastic to produce composite plastic fence posts or to CloseTheLoop / EWood who shreds and uses the plastics to make plastic wood planks for garden beds/furniture
Step 5 (Accessories and Mixed Plastics): Accessories and mixed plastics are processed by TES-AMM in Singapore. Here, they are shredded and the plastics are separated from the ferrous and non-ferrous metals for re-use. The plastics are used to make shipping pallets and the metals sold on to manufacturers.
Step 6 (Packaging): Packaging is separated into plastic and paper and sent to local recyclers for processing.

[14] http://www.mobilemuster.com.au/

(5) Case Study
Vietnam Recycling Platform [15]

Vietnam Recycles is run by the Vietnam Recycling Platform (VRP), a consortium of leading producers of electrical and electronic equipment founded to reduce electronic waste, increase recycling and manage the environmental, health and safety impact of products at their end of their life cycles. VRP was founded by Hewlett-Packard Asia Pacific Pte. Ltd. and Apple South Asia Pte. Ltd. to establish environmentally sound, safe collection and recycling processes. The program - named Vietnam Recycles - is a free take-back program for used or defective electronic products with an aim to ensure their safe and environmentally sound recycling.

The program supports both producers and consumers and is fully compliant with the recent Prime Ministerial Decision about the collection and treatment of discarded products which came into effect Jan 1, 2015 and sees manufacturers of electronic products responsible for receiving and treating/recycling electronic waste for environment protection. Vietnam Recycles will collect and process all used or defective electronic products in a safe and professional manner to ensure highly professional waste treatment and achieve maximum recovery of natural resources. It provides free take-back and recycling services for governmental agencies, institutions and enterprise customers in the Hanoi and Ho Chi Minh City regions since end January 2015. Starting end-June and end-July 2015, the program will be open to consumers where they can drop-off their used or defective IT products in Ho Chi Minh City and Hanoi respectively. All used or defective electrical and electronic equipment returned through the program are safely collected and professionally processed to achieve maximum recovery of natural resources and ensure highly professional waste treatment.

(6) Case Study
Australia's National Television and Computer Recycling Scheme [16]

The National Television and Computer Recycling Scheme (NTCRS) is the largest producer responsibility scheme ever to roll out in Australia and was the first to be established under the Australian Government's *Product Stewardship Act 2011*. The Act came into effect on 8 August 2011 and provides the framework to effectively manage the environmental, health and safety impacts of products, including those impacts associated with the disposal of products. The Product Stewardship (Televisions and Computers) Regulations 2011 (the Regulations) underpin the scheme and came into effect on 8 November 2011. The scheme does not cover all waste televisions and computers in Australia. Rather, it is part of a shared, Council of Australian Governments (COAG)-agreed approach to managing this waste stream between industry and all levels of government.

Under the NTCRS, the television and computer industries are required to fund collection and recycling of a proportion of the televisions and computers disposed of in Australia each year, with the aim of delivering a staged increase in the rate of recycling of televisions and computers in Australia from an estimated 17 per cent in 2010–11 to 80 per cent by 2021–22. The remaining waste televisions and computers, along with all other e-waste, remains the responsibility of state and territory governments and, through them, local governments.

[15] http://www.vietnamrecycles.com/about-vietnam-recycles
[16] http://www.environment.gov.au/protection/national-waste-policy/television-and-computer-recycling-scheme

In 2014–15 industry is required to recycle 35 per cent of waste televisions and computers, while state, territory and local governments are responsible for 65 per cent of television and computer waste. Industry's share of the waste stream must be recycled under the scheme. The Regulations do not prescribe any requirements for state and territory governments managing e-waste outside the scheme, and this proportion of e-waste may be dealt with as is deemed appropriate in each jurisdiction. In instances where state and territory governments choose to implement landfill bans on e-waste, alternative disposal methods must be made available to the community. With a final capacity of 80 per cent at the end of the rollout period, there will always be e-waste which needs to be managed outside the scheme. If alternative options are not made available at the jurisdictional level, there is a serious risk of illegal dumping and other adverse environmental outcomes.

Collection and recycling of e-waste under the scheme is managed through approved co-regulatory arrangements, which are administered by industry. Companies importing or manufacturing over a specified threshold of television or computer products are liable under the scheme and must join and fund an approved co-regulatory arrangement to provide collection and recycling services on their behalf.

The co-regulatory model is a key design feature of the NTCRS. Under this model, the Australian Government, through the Regulations, has set the outcomes to be achieved by industry and how this is to be monitored and reported. The television and computer industries, operating through the approved co-regulatory arrangements, determine how to deliver these outcomes efficiently. The co regulatory, market-based model was chosen because it enables lower regulatory cost and more efficient achievement of outcomes than a mandatory approach, while still addressing the free rider problem that may occur under voluntary approaches.

Each approved co-regulatory arrangement is required to achieve a portion of the total scheme recycling target, based on the import or manufacture share of its members. Recyclers and other service providers are contracted by the co-regulatory arrangement administrators through a competitive market. These contracts are private commercial agreements between co-regulatory arrangements and third parties. The co-regulatory arrangements are not obliged to work with local governments, although some are contracting or partnering with local governments to provide collection services. Some co-regulatory arrangements are providing collection services primarily through alternative channels, such as electrical retail outlets. From 1 July 2014, the NTCRS required co-regulatory arrangements to meet a material recovery target of 90 per cent, meaning that 90 per cent of the weight of televisions and computers recycled under the NTCRS must be processed into materials that are able to be re-used or manufactured into new products. Each co-regulatory arrangement is also required to provide access to recycling services for communities across metropolitan, regional and rural Australia. This requirement ensures that approximately 97 per cent of the Australian population has access to scheme services.

Administrators applying to establish co-regulatory arrangements are assessed by the Department, and are required to demonstrate capacity to achieve collection and recycling outcomes, address environmental, health and safety matters, and administer governance arrangements for liable parties. Five industry-run co-regulatory arrangements have been approved to administer the scheme and provide waste collection and recycling services: DHL Supply Chain (Australia) Pty Limited, Australia and New Zealand Recycling Platform Limited (ANZRP), E-Cycle Solutions Pty Ltd, Electronics Product Stewardship Australasia and Reverse E-Waste. The above case studies illustrate various business models that can be used for resource recovery and recycling of e-waste. Key feature of most of these case studies is the incorporation of private sector through various mechanisms to encourage environmental sound and economically efficient practices towards resource recovery and recycling.

3.0 Role of E-waste Inventory, EPR, Private Sector & Manufacturers, PPPs in Transforming E-waste Sector into an Economic Industry

3.1 Role of E-waste Inventory

Previous sections of this paper has clearly identified the resource recovery and recycling opportunities related to e-waste industry. In order to make use of these opportunities it is essential that a reliable inventory is developed for the generated e-waste. Globally, it is recognized that there is a lack of reliable data on the generation, collection, import and exports, and management schemes in general. As a result, number of countries are in the process of initiating surveys to better define the problem, to identify toxic constituents in end-of-life EEE, to develop pilot projects on successful collections, and develop infrastructure to be able to locally refurbish and recycle such used and end-of-life equipment. Proper inventory will also assist the recycling business to evaluate the resource recovery potential of valuable materials contained in e-waste. It can also be used to identify and target those types of equipment that have the greatest potential for impacting on human health and the environment.

IPEN (2013) [17] cites UNEP (2007) [18] following important steps in developing an e-waste inventory:

Step 1: Determine the e-waste item(s) of interest, such as computers, televisions (TVs), mobile telephones, and refrigerators. Compile a list of the brands in the market, the year they entered the market and also whether the items are produced/assembled locally, nationally or internationally. The existence of unbranded / un-named items also needs to be noted for recording in the inventory.

The end-of-life electronic appliances vary depending on the type of products and the technology for which they are employed. In developing countries, some products' life time could be longer than stated in the guarantee or certification card from the manufacturer, such as a refrigerator and a TV set due to the existence of service repair shops and the purchasing power of the users to replace such items. In contrast, the life time of some e-products such as mobile phones, tends to be less than stated by the manufacturers due to rapid changes in the life style and fashion of the users as well as the very rapid development in technology.

Step 2: For each category of interest by item and brand, determine the average weight and size in relation to where they are produced, i.e. locally, nationally and internationally. For example, the capacity of refrigerator (litres)/ washing machine, size of monitor/ TV/ cellular phone. The variation in size of each item should be documented under each brand. Average weight and size along with percentage composition of major categories of materials, such as plastic, glass, etc should be estimated if possible.

[17] IPEN (2013) Guide for Conducting an E-waste Inventory in Africa
http://www.ipen.org/documents/guide-conducting-e-waste-inventory-africa
[18] UNEP (2007) E-waste Volume 1: Inventory Assessment Manual
http://www.unep.or.jp/ietc/Publications/spc/EWasteManual_Vol1.pdf

Step 3: Determine the range of e-waste items likely to be available from different sources, like service industries such as hotels for TVs, fridges and air conditioners, educational institutions and businesses for computers, etc.

Step 4: Establish the geographical boundary / system boundary of the inventory area (city/ region). Procure maps of the general area and prepare base maps of the areas to be included in the inventory with physical features marked on them. If detailed maps are not available, procure and use a general city map and fix and mark the municipal boundaries.

Step 5: Identify the different users of the categories of electronic and electrical equipment and other important stakeholders like importers, manufacturers, businesses, government offices, and retailers, all of whom are consumers who would also be e-waste generators, and mark them on the base map, may be on an over-lay transparent layer.

Step 6: Prepare a tentative e-waste trade value chain.

Step 7: Identify e-waste dismantling sites, recycling sites and landfills as well as other uncontrolled dump sites.

Step 8: Identify the data needed to be collected from these stakeholders based on their activity areas and where they come in the trade value chain. These include:

- Production and import data for the identified electrical and electronic equipment
- Sales and export data for electrical and electronic equipment
- Local e-waste generation data
- Imported e-waste data and
- Data of e-waste transferred for disposal/ treatment/ reuse.

3.2 Role of Private Sector/Manufacturers and Public Private Partnerships (PPPs)

The private sector (EEE manufacturers) and public sector (national and local governments) must work closely in order to meet the overall objectives of e-waste management. Governments require the assistance from the private sector to develop proper infrastructure to turn the growing e-waste problem into an opportunity. Environmental sound and economically efficient resource recovery and recycling of e-waste cannot be achieved by public sector (national of local governments) alone. In this regard it is very useful to explore the strengths that private sector can bring in to assist the public sector. Local governments need to explore opportunities to create shared value, where businesses and the community benefit from a product or service provided by the private sector. Private sector firms can derive economic benefits by reducing risk, enhancing productivity and expanding markets, while making a substantive contribution to improved and equitable service delivery by municipalities. Such arrangements are generally referred to as public private partnerships (PPPs). PPP is a long or medium term arrangement between the public and private sectors whereby public sector transfers part of its responsibilities to the private sector. These arrangements are typically formed with clear goals and agreements for delivery of public services or delivery of public infrastructure. In simple terms, PPPs are multi-stakeholder approaches that bring together partners from different sectors with strong interest in service delivery for common public goods. PPPs have proven to be remarkably successful in both accelerating progress in service delivery and areas such as environmental management, including business and value-chain programming. E-waste resource recovery and recycling industry is not an exception.

The above partnerships can only materialise if the enabling conditions are met for both government and private sector. Cheong (2012) [19] has identified following as what to EEE manufacturers need from the government to create enabling conditions for the private sector to enter the e-waste resource recovery and recycling market:

Environmental regulation should provide a framework for reaching environmental standards but not the tools and means how it has to be achieved. It should also aim at high global harmonization, promote free movement of goods and support innovation.

- Regulation should create incentives for voluntary environmental improvements
    - *Voluntary agreements within the industry to be preferred to legislation*
    - *Regulation should recognize and award market leaders*

- Environmental regulation should be fair and reasonable
    - *Different stakeholders have equal rights or obligations*
    - *Rights and obligations understandable and easily verified*
    - *Legislation sets the generic objectives, not the operative means of achieving them*

- Each party should be made responsible only for the part of the value chain which they can directly influence.
    - *Clear definition of responsibilities for different actors in the chain*
    - *Transparency of decision making*

- Effective regulatory initiatives from environmental, economic and health and safety perspectives
    - *Competition between technologies, End-Of-Life solutions and enterprises should be encouraged*
    - *Technological development, rapid R&D cycles and the functioning of the market to be ensured*

- Industry should participate in decision making, especially when fees and exemptions as well as rules for handling of collected material are in question.
    - *End-of-life costs are kept as low as possible (allow competition between technologies and schemes)*
    - *Manufacturers can get enough control over take-back flows at acceptable cost*

- With the current limited recycling / treatment capacity (at international standards) in many countries, manufacturers and importers should be given the option of treating the collected wastes in their overseas contracted treatment facilities via the proper Basel Convention export/import permit requirements.
- Legislation should support and advocate the EPR as an environmental policy approach to manage post-consumer e-wastes

[19] Cheong, F (2012) What do electronic manufacturers need from governments? A presentation made on behalf of Nokia at the Multi-Stakeholder Policy Dialogue for Addressing E-waste Challenges and Opportunities through Public-Private Sector Cooperation, Osaka, Japan, 18-20 July

- Legislated target for e-wastes collections should be avoided if possible and instead Producer Responsibility Organisation (PRO) schemes should be encouraged.

- Obligations for manufacturers and importers should be based on the actual e-waste arising model, as opposed to products Put on Market (POM) or import volumes or sales of previous year. Different products have different shelf life and perceived values, it will be reasonable to state that different products will also have different 'discard rates'. Therefore, having a universal collection target for all products and expecting the consumers to discard the products purchased in the previous years would be difficult to justify.

- Legislation should reflect the collective responsibility for historical waste

The remainder of this section of the Paper will illustrate some examples of partnerships developed around the world for sustainable resource recovery and recycling of e-waste.

Example 1
Solving the E-waste Problem (StEP) Initiative [20]

The Solving the E-waste Problem (StEP) Initiative is a United Nations led public-private partnership hosted by the United Nations University with following mission:

- To foster inclusive solutions-oriented member dialogue, cooperation and consensus by providing a global platform for sharing information, knowledge and recommendations founded on expert scientific research and multi-stakeholder sectoral experience.
- To work internationally with receptive external partners to develop fair and objective policies to stimulate and demonstrate practical, measured and effective responses to e-waste prevention, management and processes
- To lead the e-waste management discussion worldwide by providing a scientific basis from which to inform and actively change the awareness, knowledge, attitudes and behaviour of the international business and consumer public

StEP membership is open to companies, governmental organizations, academic institutions, NGOs and international organizations that commit to actively and constructively participating in StEP's work by signing StEP's Memorandum of Understanding. StEP members are expected to make monetary and in-kind contributions to support the Initiative and its projects. The objectives of StEP include e-waste research and piloting, strategy and goal setting, and training and development. These objectives are achieved through following task forces:

- Task Force Policy
- Task Force ReDesign
- Task Force ReUse
- Task Force ReCycle
- Task Force Capacity Building

StEP regularly publishes white papers and green paper on e-waste. Following are some examples:

[20] http://www.step-initiative.org/

1. StEP White Paper on One Global Definition of E-waste [21]
This publication deals with the issue of how to define e-waste. The intent of this paper is to provide a non-legal definition of the term and clarity about how the term should be used.

2. StEP Green Paper on Differentiating EEE Products and Wastes [22]
This publication discusses the provisions of the Basel Convention that concern e-wastes, and it further examines the potential impact of the Draft technical guidelines on transboundary movements of e-waste and used electrical and electronic equipment.

3. StEP Green Paper on E-waste Prevention, Take-back System Design and Policy Approaches [23]
This publication explores the large variety of e-waste policy options that have been implemented globally and it draws some conclusions about the nature of responses to the e-waste problem and potential policy recommendations.

Example 2
Basel Convention Partnership for Action on Computing Equipment (PACE) [24]

The Partnership for Action on Computing Equipment (PACE) is a multi-stakeholder partnership established to address the environmentally sound management of used and end-of-life computing equipment. The multi-stakeholder Working Group, comprised of representatives of personal computer manufacturers, recyclers, international organizations, academia, environmental groups and governments developed the proposed scope of work, terms of reference, financial arrangements, and structure of PACE. The Partnership was launched at the ninth meeting of the Conference of the Parties to the Basel Convention, which took place in Bali, Indonesia in June 2008.

The Partnership covers Personal Computers (PCs) and associated displays, printers and peripherals, that include: personal desk top computer, including the central processing unit and all other parts contained in the computer; personal notebooks and laptop computers, including the docking station, central processing unit and all other parts contained in the computer; computer monitors, including the following types of computer monitors:(a) cathode ray tube(b) liquid crystal display(c) plasma; computer keyboards, mouse, and cables; Computer printers:(a) including the following types of computer printer:(i) dot matrix(ii) ink jet(iii) laser(iv) thermal and(b) including any computer printer with scanning or facsimile capabilities, or both.

PACE has achieved following tasks:

- Identified relevant existing environmentally sound management guidance materials and prepared a report on environmentally sound management criteria recommendations that were used by other Project Groups;

[21] http://www.step-initiative.org/files/step/_documents/StEP_WP_One%20Global%20Definition%20of%20E-waste_20140603_amended.pdf
[22] http://www.step-initiative.org/news/step-releases-green-paper-exploring-legal-distinction-between-ueee-and-e-wastes-in-basel-convention.html
[23] http://www.step-initiative.org/news/step-green-paper-explores-policy-solutions-to-e-waste-problem.html
[24] http://www.basel.int/Implementation/TechnicalAssistance/Partnerships/PACE/Overview/tabid/3243/Default.aspx

- Completed guidelines, one on environmentally sound testing, refurbishment and repair of used computing equipment; and the second one on environmentally sound material recovery and recycling of end-of-life computing equipment;
- Initiated the process to identify countries for pilot projects on collection and management of end-of-life computing equipment from informal sectors in developing countries and countries with economies in transition, which should divert end-of-life computing equipment from landfills and open-pit burning;
- Finalized guidance on transboundary movement of used and end-of-life computing equipment;

Example 3
Basel Convention Mobile Phone Partnership Initiative (MPPI) [25]

The Mobile Phone Partnership Initiative (MPPI) was launched in 2002 when 12 manufacturers entered into a sustainable partnership, with the Basel Convention and in cooperation with other stakeholders, to develop and promote the environmentally sound management of end-of-life mobile phones. The overall objective of the MPPI Work Programme, which involved many stakeholders besides the partners, was to promote the objectives of the Convention in the area of the environmentally sound management of end-of-life mobile phones. In particular, the MPPI Work Programme was developed to:

- Achieve better product stewardship;
- Influence consumer behaviour towards more environmentally friendly actions; • Promote the best refurbishing/recycling/ disposal options;
- Mobilise political and institutional support for environmentally sound management;
- Result in an initiative that could be replicated to build new public/private partnerships for the environmentally sound management of hazardous and other waste streams

The benefits of the MPPI can be summarized as follows:
- Consumers should have confidence that re-sold phones processed in accordance with the guidelines are of a satisfactory standard with respect to product safety, quality, longevity and environmental performance.
- Manufacturers should have confidence that both importers & local reprocessors are aware of the best practices with respect to refurbishment, materials recycling, transboundary movements, and implement these for products they manufactured.
- International organizations, such as UNEP, benefit by the fact that partnerships such as the MPPI make concrete contribution to the implementation of sustainable development goals, outlined in environmental agreements such as the Basel Convention. It also contributes towards the implementation of Agenda 21, and Johannesburg Plan of Implementation.
- Partnerships like the MPPI complement government’s initiatives to deliver on goals and objectives under various environmental agreements, while promoting cooperative sustainable and transparent working arrangements with all stakeholders.

Example 4
South African E-waste Alliance (SAEWA) [26]

[25] http://www.basel.int/Implementation/PartnershipProgramme/MPPI/Overview/tabid/3268/Default.aspx
[26] http://sa.ewastealliance.co.za/

The South African E-waste Alliance (SAEWA) is multi-stakeholder partnership and a non-profit organisation which helps to coordinate responsible management of the entire e-waste stream in a one-stop shop format nationwide. The SAEWA business cooperation and waste beneficiation model allows its members optimize their goals by minimizing waste and maximizing resource use and job creation, and adding value in each step of the e-waste.

Some outcomes of the SAEWA business partner collaboration include:

• An increase in the quantity of pre-owned equipment that is available to registered community based charitable organizations, as a result of a comprehensive rebuild program.
• The establishment of a safe environment where non-working equipment and sub-systems can be disassembled to a component level, in order to recover materials that in their own right have intrinsic scrap value, or value to a third party in a creative environment.
• Satisfaction of current and future legal requirements while being financially feasible and safe with regards to data protection and convenient with regards to collection services offered.

Example 5
E-waste Alam Alliance Malaysia [27]

E-waste Alam Alliance Malaysia was launched on 11 December 2013 by the Deputy Minister of Natural Resources and Environment, Y.B Dato' Sri Dr. James Dawos Mamit. The objectives of partnership are:

- Implementation of collection, segregation and transportation of the waste of e-waste generated from households effectively;
- Develop a system of collection, segregation and transportation of e-waste from households across Malaysia centralized;
- Increase public awareness will be the responsibility of the waste of e-waste from households owned;
- Increasing awareness of the producer / seller / distributor of electrical and electronic goods on the importance of being responsible for the management of e-waste from households;
- Encourage manufacturers / vendors / distributors of electrical and electronic waste collection to implement e-waste from households voluntarily and without additional charge;
- Creating a network of cooperation with stakeholders in the management of e-waste from households

E-waste Alam Alliance involves number of stakeholders as described below:

- Six States namely Perak , Selangor , Federal territory(Kuala Lumpur and Putrajaya), Melaka and Johor;
- Local authorities in each state;
- Manufacturers / Dealers (Retailers) / distributor / importer of electrical and electronic goods in each state;
- Off Site Recovery Facility (Full Recovery Facility);

[27] http://www.doe.gov.my/portalv1/wp-content/uploads/2014/02/Information-for-inclusion-in-the-DOE-Portal.pdf

- National Solid Waste Management Department (JPSPN) / Solid Waste Management and Public Cleansing (PPSPA)
- Charitable non-governmental organizations (NGO's) / community / residents association

3.3 Role of Extended Producer Responsibility (EPR)

EPR is regarded an environmental policy approach in which a producer’s responsibility for a product is extended to the post-consumer stage of a product’s life cycle. EPR typically involves a shift in administrative, physical and financial responsibility from governments or local authorities to producers. EPR also encourage producers to take environmental considerations into account during the design and manufacture phases of product development thereby seeking to achieve a reduction in the environmental impact of products, throughout their lifespan, from production through end-of-life.

The European Union pioneered the mandating EPR for management of e-waste. European Union’s Waste Electrical and Electronic Equipment Directive (WEEE Directive) is one of first EPR systems to develop in e-waste field. Subsequently, number of industrialised counties have developed EPR is some form and number of developing countries are currently developing similar schemes with some challenges.

There are four broad categories of EPR instruments at the disposal of policy makers. These typically address specific aspects of waste management, and can be implemented concurrently:

- Product take-back schemes that require the producer or retailer to collect the product at the post-consumer stage. This objective can be achieved through recycling and collection targets of the product or materials and through incentives for consumers to bring the used product back to the selling point. Such schemes are administeted by independent bodies commonly known as Producer Responsibility Organisations (PROs).

- Economic and market-based instruments that include measures such as deposit-refund schemes, Advanced Disposal Fees (ADF), material taxes, and upstream combination tax/subsidy (UCTS) that incentivize the producer to comply with EPR. In The Republic of Korea for example, ADFs are imposed on importers and producers of products that are hazardous and more difficult to recycle.

- Regulations and performance standards such as minimum recycled content that can be mandatory or applied by industries themselves through voluntary programmes.

- Information-based instruments that aim to indirectly support EPR programmes by raising public awareness. Measures can include imposing information requirements on producers such as reporting requirements, labelling of products and components, communicating to consumers about producer responsibility and waste separation, and informing recyclers about the materials used in products.

The key objective of EPR is to support improvements in the environmental efficiency of products throughout their life cycle. The following are regarded as possible achievements of EPR:

- Increased collection and recycling rates and increased environmental effectiveness

- Reduction of public spending on waste management
- Reduction in overall waste management costs
- Innovation and implementation related to Design for Environment (DfE)

There are also a number of challenges and constraints to implement EPR. They include unclear and overlapping roles and responsibilities of different actors, a lack of transparency and difficulties in the comparability of data, concerns with free-riding, a lack of enforcement mechanisms, difficulties on deciding fees etc. The detailed analysis of issues, challenges and opportunities related to planning and implementing EPR is described in a issues paper published by OECD [28]. Following is a summary of those challenges:

- Unclear and overlapping roles and responsibilities of different actors (PROs, producers, importers, collectors and recyclers, municipalities and consumers)

- A lack of transparency and difficulties in the comparability of data

- Concerns with free-riding (free-riding occurs when some producers do not finance the collection and recycling of their products up to the level requires or the producers do not provide accurate data about the quantities of products put on the market)

- A lack of enforcement mechanisms (issues impacting EPR such as free-riding, competition concerns, illegal landfilling, exports of waste and used products require permanent monitoring and control by public authorities)

- Difficulty to implement differentiated fees and lack of incentives for design for environment

- Informal waste management sector and social challenges

- Waste leakage (e-waste not captured by the EPR scheme but instead collected and treated through other legal or illegal channels)

- Orphan products (these products were put on the market before the introduction of EPR schemes by producers who are no longer in business)

EPR Case Study [29]

Source: Veit, R. (2015) Global E-waste Regulation and Policy Trend. Paper presented at the 3W Expo and Conference E-waste Asia 2015, Bangkok.

This case study describes possible models for implementing EPR in Asia-Pacific region and some examples of EPR operation in selected countries.

State Fund Model

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[28] OECD (2014) Issues Papers on the State of Play on Extended Producer Responsibility (EPR): Opportunities and Challenges
http://www.oecd.org/environment/waste/Global%20Forum%20Tokyo%20Issues%20Paper%2030-5-2014.pdf

[29] http://www.iswa.org/media/publications/knowledge-base/?tx_iswaknowledgebase_filter%5Bcategories%5D=all&tx_iswaknowledgebase_filter%5Bmaincategories%5D=0%2C1&tx_iswaknowledgebase_list%5Bpage%5D=4&tx_iswaknowledgebase_list%5Bsorting%5D=crdate&cHash=660882cac3e8bfb176dcc1800128eb34

In this model producers are held only financially responsible for the costs of waste collection and treatment through payment of fees or taxation to a designated waste management fund. The organisational responsibility for waste management and for the decision about which waste collection operations to use lies with a government controlled organisation.

Single Organisation Model

In this model an entire industry sector placing a product group on the market commits to financing and organising waste management through a single compliance organisation, often on the basis of an environmental agreement with the government.

Competing Organisation Model

In this model the government authorises several compliance organisations to whom a producer may transfer financial and organisational obligations.

Examples

Australia has adopted the Competing Organisation Model for televisions and computers. The National Television and Computer Recycling Scheme requires the television and computer industries to fund collection and recycling of a proportion of the televisions and computers disposed of in Australia each year. The scheme's long-term goals include the diversion of potentially hazardous television and computer waste from landfill, an increase in the recovery of useable materials and greater access to recycling for communities across Australia.

The scheme's design includes a stepped implementation over a number of years, with industry taking responsibility for a progressively higher proportion of total waste televisions and computers each year, from 30 per cent in 2012–13 to 80 per cent by 2021–2022. Television and computer waste beyond these targets remains the responsibility of state, territory and local governments. Companies importing or manufacturing over a specified threshold of television or computer products are liable under the scheme and must join and fund an approved co-regulatory arrangement to provide collection and recycling services on their behalf. All liable parties met their obligation to join a co-regulatory arrangement in 2012–13. Three approved co-regulatory arrangements were operational in 2012–13: DHL Supply Chain (Australia) Pty Limited, Australia and New Zealand Recycling Platform Limited (ANZRP) and E-Cycle Solutions Pty Ltd.

4.0 Role of R&D and Technology Transfer as Key Driver for Harnessing Economic Potential of E-waste Sector

4.1 Role of R&D

In order to understand the role of R&D towards environmentally sustainable resource recovery and recycling of e-waste, it is necessary to understand the current issues that exist in the manufacturing process of EEE. The traditional manufacturing process in the electronics industry has been linear in nature and adheres to the standard "profit" focused approach which can be regarded as "take-make and waste". Currently, many EEE manufacturing companies are attempting to move away from this approach. The EEE manufacturer or other industry player may well have an environmentally certified manufacturing plant and be extremely mindful of its eco-responsibility. However, if the end product is not "clean" in process, then the impact of any improvement through accreditation is weakened. It must be recognised that accreditation is but the first step towards sustainability. It is not an end in itself. Once a product is out on the market, the ability to improve its environmental performance is essentially eliminated. Resources may be expended on attempting to do so but it will be relatively ineffective and environmental impact and degradation will not be reduced. A product is like a messenger between the acts of production and consumption. They are "the carriers of material's flow, energy usage, functional performance and environmental impacts". The challenge is to ensure that an integrated circular "whole systems design" encouraging a borrow-use-return approach to be taken and the linear method abandoned. This process incorporates design for environment (DfE).

DfE or eco-design, at times also refer to as cleaner production, as a result of major regulatory changes that have and are taking place internationally and together with pressure from end-users, is becoming an increasingly important priority for manufacturers of EEE. DfE is not a compliance activity, but an integrated, cross-functional strategy. DfE is an integrated strategy that has the goal of reducing the environmental impact of a product at the design stage. DfE begins with research and development using environmental impact as the basis for the product whilst procurement and quality assurance work closely with suppliers by ensuring they meet or exceed the criteria for environmental performance. DfE will not only see the elimination of toxic products from the system altogether, better disassembly, lower weight and smaller footprints, it will enable manufacturers to achieve a level of competitive advantage over more conventional manufacturers that do not follow this path. It will also eventually eliminate these conventional manufacturers from the largest markets. DfE is not only an issue for the manufacturer, the consumer also has a part to play in the process. The consumer is the key to initiation and implementation of DfE at points along the supply chain. The consumer, particularly larger organisations such as government departments, through the implementation of purchasing policies, is in a position to encourage EEE suppliers to implement DfE by specifying criteria in contracts. This is known as environmentally responsible product purchasing (ERPP) or green purchasing.

From a resource recovery and recycling point of view, R&D plays an important role by eliminating the toxic materials in EEE and thereby increasing the efficiency of the recovery processes. Green electronic through lead-free soldering is one such example which is gaining momentum worldwide. EEE contains over 1000 materials of which lead (Pb) has been one of the targets of the regulators forcing manufacturers to adopt lead free products. Industry has come up with several lead free solders with preference given to alloys containing tin, silver and copper but there is no 'drop-in' substitute to leaded solder.

In order to gain a better understanding of available technologies for e-waste recycling and recovery, the Secretariat of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (SBC), requested World Intellectual Property Organisation (WIPO) [30] to prepare an e-waste technologies patent landscape report.
The report, published in December 2013, provides a comprehensive overview of R&D activities related to e-waste recycling and recovery, mainly concentrating on end-of-life mobile phones and computer equipment. It offers a snapshot of innovation in this field, identifies observable trends in patenting activity and provides insights about the technology

[30] WIPO (2013) Patent Landscape Report on E-waste Recycling Technologies, Prepared by World Intellectual Property Organisation in collaboration with Basel Convention
http://www.wipo.int/edocs/pubdocs/en/patents/948/wipo_pub_948_4.pdf

development cycle, the geographic distribution of innovation, research topics and primary actors, including case studies, within e-waste and related research and development.

The report analyses patent applications relating to e-waste recycling in three main categories, namely: technologies for recycling or recovering materials such as plastics or metals; sources of e-waste and their processing (e.g. batteries, cabling and printed circuit boards); and processes and logistics involved in e-waste treatment, such as magnetic sorting of e-waste. The report shows that bulk of e-waste innovation is taking place in Asia (followed by Europe and the US) with Japanese consumer electronics and metals firms, such as Panasonic, Hitachi and Toshiba, representing the largest and most dominant patent portfolios with over 50 percent of all activity. PR China is also emerging as a key player, with domestic e-waste-related patenting activity increasing seven-fold in just six years. The complete details of R&D activities of number of EEE manufacturers around the world can be found in WIPO (2013).

4.2 Role of Technology Transfer

According to (UNEP and UNU, 2009a)[31], the e-waste recycling chain mainly consists of collection, sorting/dismantling and pre-processing and end-processing. All the above steps need to operate in a holistic manner to achieve the following objectives:

- Treat the hazardous compounds contained in e-waste in an environmentally sound manner
- Recover valuable material using efficient processes
- Create economically and environmentally sustainable businesses
- Consider social impact and local context of operations

In order to have a successful e-waste recycling system, it is important to achieve maximum efficiencies in all the components in the recycling chain. The above report cites an example where for a certain metal or device in the e-waste stream the efficiency of collection is 50%, the combined dismantling pre-processing efficiency is 70% and final materials recovery efficiency is 95%, the resulting in final collection efficiency of only 33%. UNEP and UNU (2009a) identifies number of barriers for the transfer of sustainable e-waste recycling technologies. These are summarised below:

Policy and Legislation Barriers
- Lack of dedicated legislation dealing with e-waste
- Confusion created by attempting to cover e-waste through legislations related to other media such as environment, water, air etc as each of them examine the e-waste issue in different perspective
- Enforcement of laws undertaken by different government departments without any uniform approach
- Players in e-waste being not recognised by the policy and legislative framework
- Existence of strong social programs that exist to support the informal e-waste recycling sector
- High level corruption in law enforcement
- Low national priority for e-waste

[31] UNEP and UNU (2009a), Sustainable Innovation and Technology Transfer Industrial Sector Studies: Recycling – From E-Waste to Resources, Published jointly by UNEP and United Nations University (UNU) http://www.unep.org/PDF/PressReleases/E-Waste_publication_screen_FINALVERSION-sml.pdf

Technology and Skills Barriers
- Lack of enforcement of Environmental Health and Safety (EHS) standards among the workers
- Lack of certification of e-waste recyclers and refurbishers
- Lack of a mechanism to separate e-waste from solid waste
- Lack of collection system leading to e-waste being stockpiled in homes and offices
- No infrastructure available for the disposal of hazardous fraction of e-waste
- Recycling business is mainly in the hands of the informal sector
- Current recycling system concentrates on generating good revenues hence no interest in more sustainable technologies

Business and Financing Barriers
- No or limited producer/distributors responsibility
- High cost of logistics especially in transport and hazardous waste disposal
- Exploitation of informal workers in a formalised e-waste recycling industry
- Consumers expect to be paid for broken equipment

Technology Transfer Case Study

The challenge of e-waste management is that it contains not only hazardous materials but also some valuable materials. It is well documented that used electronics are shipped to developing countries for reuse but most of them end up as e-waste in a very short time. The unsophisticated, informal recycling common in many developing countries pollutes the environment. It is now becoming clear that the developing and transition countries have been producing more e-waste than the developed countries where formal facilities exist to properly manage e-waste. Thus, innovative models for technology transfer are needed to tackle the problem until developing countries are better equipped to deal with e-waste by themselves.

This case study describes an innovative model developed by the Solving the E-waste Problem (StEP) initiative where it is argued that affordable and environmentally sound recycling can be achieved in developing countries through the cooperation between local dismantling operations and the global networks of infrastructure that ca further refine the materials. The concept referred to as 'Best-of-2-Worlds" (Bo2W) aims to integrate technical and logistical strengths in advanced end-processing facilities.

Dismantling of e-waste undertaken in developing countries can be a very efficient method to separate materials and components from e-waste due to low labour costs and little need for advanced equipment. At the same time, fractions such as circuit boards require high-tech treatment that is usually unavailable in developing countries. The Bo2W concept connects the best pre-processing already occurring in developing countries (manual dismantling) with the best end-processing (material refinery and disposal) in global treatment network.

5.0 The Way Forward

E-waste is regarded as the world's fastest growing waste stream. The rapid development of the information and communication technology sector has brought with it many life-enhancing advantages and opportunities. The downside, however, is that the scale and speed of technical innovation in this area, fuelled by our limitless appetite for next generation technologies, as well as the global uptake of these low-cost devices. Out of the 41.8Mt of e-waste generated globally in 2014 only 6.5Mt (around 15%) was reported as formally treated by national take-back schemes which employ environmentally sound resource recover practices. Much of the remaining e-waste ends up in developing countries where it is often recycled by the informal sector using rudimentary methods that present significant risks to the environment and the health of local populations. Unlike other types of municipal waste, e-waste involves a complex mix of hazardous, highly toxic materials and economically valuable, noble metals. As up to 60 elements from the periodic table can be found in complex electronic equipment, sophisticated processing technologies are required to maximize the recovery of these valuable resources while minimizing any negative social or environmental impact. This presents both challenges and opportunities for recyclers.

There is a growing perception that e-waste is a valuable resource with huge potential for resource recovery and recycling of valuable materials, especially the metals. Electronic devices are an alternative source of base metals such as copper (Cu) and tin (Sn), special metals such as cobalt (Co), Indium (In) and antimony (Sb) as well as noble metals such as silver (Ag), gold (Au), palladium (Pd) and platinum (Pt). Although the quantities used in each individual device are small, when you consider the global sales of these devices are significant providing the economic benefits of recovering and recycling.

The Asia-Pacific region is the highest contributor to the global e-waste stream. Given that most of the emerging economies are located in this region it is clear that this trend will continue well into the future. The Regional 3R Forum for Asia and Pacific, launched in November 2009, with an objective to provide strategic policy advices to national government authorities in mainstreaming 3Rs in the overall policy, planning and development, has identified and called action for environmentally sound management of e-waste in the Asia Pacific region during number of meetings held in the past as illustrated below:

Tokyo 3R Statement – Towards the Establishment of the Regional 3R (Reduce, Reuse and Recycle) Forum in Asia – 2009, Tokyo, Japan
Item 2(f)

*"Building adequate **capacity for collection and safe treatment of hazardous waste,** including those from household waste and **e-waste**;"*

Recommendations of the Singapore Forum on the 3Rs in Achieving a Resource Efficient Society in Asia, 2011 Singapore
Item A (3)

"Large amount of e-waste generated in the world ends up in a few numbers of developing countries for the purpose of reuse, refurbishment, recycling, and recovery of precious materials. E-waste has become an important health and environmental issue, as recycling electronic goods involves exposure to dangerous heavy metals such as lead, mercury,

cadmium etc. which can be toxic to human and ecosystems. The countries can consider the following.

- *Establish proper institutional infrastructures for collection, storage, transportation, recovery, treatment and disposal of e-waste at regional and national levels. Such infrastructure should be integrated into existing waste collection schemes. Develop public-private-community partnerships to encourage the establishment of formal e-waste recycling and disposal enterprises.*

- *Establish appropriate regulatory procedures to control illegal exports of e-waste and to ensure their environmentally sound management. In this regard, proper testing of used or end-of-life electronics and electrical equipment prior to export should be encouraged to declare the presence of hazardous components as well as the functionality of the equipment.*

- *Introduce awareness raising programmes and activities at all levels on issues related to health and safety aspects of e-waste in order to encourage better management practices.*

- *Establish formal standards, certification systems and licensing procedures for recycling and disposal enterprises to ensure safety and environmentally sound processing of e-waste.*

- *Implement 'extended producer responsibility' (EPR) mandating producers, importers and retailers with the cost of collecting, recycling and disposal of e-waste. Thorough investigation into the problems and challenges of implementing EPR should be conducted to overcome any obstacles."*

Ha Noi 3R Declaration – Sustainable 3R Goals for Asia and the Pacific for 2013-2023, Ha Noi, Vietnam- Item III 3R Goals for New and Emerging Wastes (Goals 13, 14, 15)

*"Goal 13: Ensure **environmentally-sound management of e-waste** at all stages, including collection, storage, transportation, recovery, recycling, treatment, and disposal with appropriate consideration for working conditions, including **health and safety aspects** of those involved.*

Goal 14: Effective enforcement of established mechanisms for preventing illegal and inappropriate export and import of waste, including transit trade, especially of hazardous waste and e-waste.

*Goal 15: Progressive implementation of **"extended producer responsibility (EPR)"** by encouraging producers, importers, and retailers and other relevant stakeholders to fulfill their responsibilities for collecting, recycling, and disposal of new and emerging waste streams, in particular e-waste."*

Surabaya Decalaration on Promotion of Multilayer Partnerships and Collaboration for the Expansion of Reduce, Reuse and Recycle (3Rs) in Asia and the Pacific, 2014, Surabya, Indonesia

***"Recognizing** the complex and daunting nature of waste management challenges faced by local authorities and municipalities in today's world in view of the diversification of waste* *streams region-wide, the growing presence of chemicals and hazardous and toxic elements, including e-wastes, in the general waste stream, the increasing presence of waste, in particular plastics and disaster waste in coastal and marine environment that increasingly demand science-based decision-making and solutions within multilayer partnerships and collaboration,*

On-going discussions and resulting reports concerning post-2015 development agenda categorically mentions the importance waste management and 3R towards achieving the goals [32]. Some of the goals related to e-waste are illustrated below:

"11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment

12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse"

The countries in Asia-Pacific countries are experiencing a major problem with the ever-increasing amount of e-waste, as they lack the policies and infrastructure to deal with the issue in a sustainable way. Although e-waste is a problem because of its hazardous components, it is also a solution to the depletion of the natural resources that manufacturers of EEE depend on. Proper recycling of e-waste is of great importance in order to harvest these secondary sources. The e-waste recycling chain consists of three main steps: collection, sorting/dismantling, and pre-processing and end-processing. In developing countries these three activities are undertaken predominantly by the informal e-waste recycling sector, with little presence of the formal recycling sector. Although the first two of these steps can be undertaken by the informal sector without much environmental impact, the last step of end-processing, when undertaken by the informal recycling sector, could result in severe environmental impacts.

The transfer of appropriate technology to developing countries to manage their e-waste problem should be undertaken, keeping in mind their social, environmental and economic boundaries. Direct transfer of technology without any consideration given to inter-linked, non-technical aspects has led to failure in a number of cases. The collection of e-waste by the informal sector is quite efficient in a number of developing countries. Furthermore, the informal sector is quite active in the pre-processing stage of recycling operations. For example, deep level manual dismantling of used EEE in developing countries may be preferred over high-technology, automatic processes as a result of an abundant workforce and low labour costs. Deep-level manual dismantling also results in good preparation of feedstock for the subsequent steps in the recycling process. However, there is lot of room for improvement in all other informal recycling activities through technology transfer. Even with such improvements, an optimal level will be reached whereby it will no longer be feasible for

[32] UN (2015) Report of the Open Working Group of the General Assembly on Sustainable Development Goals http://www.un.org/ga/search/view_doc.asp?symbol=A/68/970

informal recyclers to process materials efficiently. State-of-the art end-processing facilities, such as integrated smelters, will be required to recover precious materials in an efficient way.

The problem is that most developing countries cannot afford the high investments for such technology, with the exception of large emerging economies or highly industrialised countries within the region. Therefore, a regional approach is more appropriate at the latter stages of end-processing of e-waste. The future success of technology transfer to countries with dominant and successful informal e-waste recycling sectors will depend on innovative models whereby the informal sectors are still allowed to participate in safe recycling practices while hazardous operations are transferred to state-of-the-art formal recyclers. Such models would require giving a high priority to further improvement of collection and pre-processing by the informal sector through technology transfer to benefit state-of-the art formal recycling operations towards the end of the recycling chain.

EPR is considered globally as one of the most powerful policy mechanisms in dealing with the e-waste problem. Most developed countries have had a lot of success implementing EPR related policies. Due to the urgency of the issue, a number of developing countries are planning or have already adopted EPR related policy mechanisms based upon the templates used in developed countries. If possible, developing countries should take care to avoid this path and try and attempt to design their own EPR schemes based upon their capacity to implement such schemes. Whichever scheme is adopted, managing e-waste is a major challenge to an individual country in the developing world due to the limitations and challenges already discussed. As such, serious consideration should be given to a regional approach, where economies of scale may be more appropriate.

In order for developing countries to move forward on EPR regulations, (Akenji *et al.*, 2011) [33] have proposed that developing countries should move gradually towards EPR in phases. They have identified competition with the informal waste management sector, poor infrastructure for waste collection and treatment, perception of e-waste and poor international governance of import and export of e-waste as key challenges facing the governments. Therefore, they have recommended that instead of following an EPR template or generic recommendations, developing countries should commence the process by setting up a multi-stakeholder panel, referred to as a 'National E-waste Expert Review' (NEWER) consisting of experts, policy makers, researchers, relevant industrial associations and consumer groups.

This review should be entrusted with following tasks:

- Review specific national situation regarding e-waste
- Extracting lessons from experiences in developing and implementing EPR systems in other countries
- Consulting with various e-waste stakeholder groups that would be affected by an EPR system, including informal waste collectors and recyclers
- Evaluating national infrastructure for e-waste management, related policies already existing, new ones needed, and the capacity to implement EPR-based policies.

Then they have recommended the following phases for implementing EPR in developing countries:

[33] Akenji, L., Hotta, Y., Bengtsson, M. & Hayasi, S. (2011) EPR policies for electronics in developing Asia: ad adapted phase-in approach. *Waste Management & Research*, **29**, 919-930.

- Phase 1: Focus on improved waste management and resource recovery (establish an interface organisation to mediate with informal sector, certification of proper recyclers, licensing repairers)
- Phase 2: Focus on integration of externalities into consumption and production (eg. product take-back, recycling fund)
- Phase 3: Focus on design for environment (design for environment)
- Phase 4: Regional/international collaboration towards better governance for resource circulation

The Institute for Global Environmental Strategies (IGES) has an Issues Brief on Applying EPR in Developing Countries. [34] This paper describes very useful policy concepts for implementing EPR in Asia-Pacific countries based on the above mentioned Phases. They are summarised below:

Phase 1 Policy Concepts
- Public awareness campaigns
- Development of basic waste separation and collection infrastructure
- Creation of interface organisation to mediate between the informal sector and resource recovery facilities
- Licensing for proper repairers
- Certification for recyclers and recycling centres

Phase 2 Policy Concepts
- Introduction of take back scheme
- Recycling Fund
- Minimum sustainability quality standard for recyclables
- Eco-industrial parks

Phase 3 Policy Concepts
- Greening the supply chain
- Green purchasing
- Restrictions on throwaway products
- Introduction of virgin material tax

Phase 4 Policy Concepts
- Multilateral financial mechanism for sustainable resource management and resource circulation

Although a number of initiatives have been implemented to achieve ESM of e-waste, there are a significant number of issues and challenges to deal with. Cooperation among the key stakeholders is the key to finding solutions to the above issues and challenges. Although there are currently a number of activities conducted by various countries and donor agencies, harmonisation of these activities is needed to maximise the limited resources.

As a way forward, the policy makers in Asia Pacific countries may find following activities useful in their attempt to achieve sustainable e-waste management, in particular, to create enabling conditions for enhancing the business and economic potential of resource recovery and recycling from e-waste:

[34] http://pub.iges.or.jp/modules/envirolib/upload/3553/attach/rio_issue_brief_vol3_EPR_mar2012.pdf

- Well defined national e-waste management strategy based upon 3R concepts. Such strategy should not only address the environmental and health impacts of e-waste (end-of-pipe) but also look at the reduction of e-waste through green design (up-the-pipe). It should also create enabling conditions for relevant stakeholders to develop business and economic opportunities to recover the materials from e-waste. The strategy should take into account the financial, institutional, political and social aspects of e-waste management, in particular, incorporating the activities of informal e-waste recycling sector
- Well defined regulatory procedure adequate enough to control illegal exports of e-waste and to ensure their environmentally sound management.
- Improve country's ability to gather data and inventory on e-waste generation including their transboundary movement and to access appropriate and cost effective technologies to manage e-waste within their own borders. Such inventory should clearly identify the key players in the e-waste recycling value chain
- Establishment of proper institutional infrastructures for collection, storage, transportation, recovery, treatment and disposal of e-waste at regional and national levels.
- Development of scientific resources such as experts and laboratories to conduct environmental and human health impacts of e-waste
- Improving the working conditions and minimisation of work related toxic exposure at e-waste collection, processing, recovery and disposal facilities.
- Awareness raising programmes and activities on issues related to health and safety aspects of e-waste in order to encourage better management practices.
- Develop public-private-community partnerships to encourage the establishment of formal e-waste recycling and disposal enterprises.
- Address the obstacles related to implementing EPR and mandating producers, importers, retailers with cost of collecting, recycling and disposal of e-waste.
- Require the countries that export used EEE to developing countries to formally test the equipment prior to export.
- Prohibit import of e-waste if the receiving country does not possess adequate capacity to manage these wastes in an environmentally sound manner.
- Identification of organisations or institutions with potential to develop innovation hubs and centres for excellence for developing and promoting environmental sound e-waste recycling technologies. These centres of excellence should conduct R&D on innovative technologies and should be able to assess the applications of relevance of technology transfer.
- Develop standards for collection, storage, transport, recovery, treatment and disposal to ensure environmentally sound management of e-waste.

5.1 Three Policy Questions

The Asia-Pacific experiencing a major problem with the ever increasing amount of e-waste as they lack the policies and infrastructure to deal with the issue in a sustainable way. Although e-waste is a problem due to its hazardous components, it is also a solution to the depletion of the natural resources which the manufacture of EEE depends upon. Proper recycling of e-waste is of great importance in order to harvest these secondary sources. This requires overcoming significant challenges and barriers through innovations in key areas such as policy making, institutional arrangements, cost recovery and technology transfer. The aim of this background paper is to stimulate discussion around the key policy questions given below to achieve the true potential of business and economic opportunities in Asia-Pacific countries towards resource recovery and recycling of e-waste.

1. Does the existing legal and institutional framework achieve true potential of business and economic opportunities towards resource recovery and recycling of e-waste?

2. What are the enabling factors to promote resource recovery and recycling of e-waste in the areas of; a) Market potential, b) Engagement of private sector and manufacturers, c) Developing PPPs, and d) Technology transfer?

3. Do existing financial arrangements for managing e-waste achieve financial sustainability? If not, what are the suitable financial mechanisms (eg. EPR) that are suitable for Asia-Pacific countries?

5.2 Key Challenges

Developing a suitable legal and policy framework to create enabling conditions for sustainable management of e-waste in Asia-Pacific countries is one of the key challenges to moving forward. EPR is seen as the most preferred option by many Asia-Pacific countries and, as a result, have developed or in the process of developing legislature related to this area. However, there are significant challenges given the current complexities of e-waste management in Asia-Pacific countries. Most Asia-Pacific countries are developing EPR systems based upon the examples from other countries, specially developed countries. This is one of the major weaknesses in policy making. The challenge is to develop an EPR system that is appropriate to the local situation. In this regard, the National E-waste Expert Review suggested elsewhere in the paper could play a major role in understanding the capabilities of each country. Without such understanding legislature or policy attempting to implement EPR system would possibly fail to implement.

Another related challenge for Asia-Pacific countries is the existence of informal e-waste recycling sector, especially junk yards who currently deal with e-waste. An EPR system based on developed countries would not function in most Asia-Pacific countries as such system would not be able to accommodate the activities of the informal sector. Formal licensing such informal enterprises is one option available for Asia-Pacific countries.

A suitable solution to above-mentioned challenges and many other country-specific issues and challenges related to e-waste can only be found by asking following three questions:

Where are we now?

Where do we like to be in 5-10 years?

How do we get there?

A well-defined national e-waste management strategy based upon the answers to the above key questions would create the enabling conditions to achieve true potential of business and economic opportunities towards resource recovery and recycling of e-waste.