Municipal Solid Waste Management and Green Economy

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GLOBAL YOUNG ACADEMY

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2016

Foreword from the GYA Co-Chairs

This "Municipal Solid Waste Management and Green Economy" report is the first of its kind released by the Global Young Academy (GYA). It is a policy report drafted by experts in the field and synthesized by scientists who are members of the GYA. The project is global in scope, multi-layered, and inclusive. This report considers issues that high, moderate, and low income countries face in seeking to address solid waste management and the green economy. The authors identify challenges that nations and stakeholders share and those that are unique to regional, social, and economic situations. The report provides both overarching regional statements and specific recommendations targeted to address case studies and similar situations.

This report provides the perspective of young scientists on the current state of research around municipal solid waste management and the green economy. The Global Young Academy was founded in 2010 with the vision to be the voice of young scientists around the world. The GYA empowers early-career researchers to lead international, interdisciplinary and intergenerational dialogue by developing and mobilizing talent from six continents. Its purpose is to promote reason and inclusiveness in global decision-making. Members are chosen for their demonstrated excellence in scientific achievement and commitment to service. In 2016 the GYA has 200 members and 134 alumni from 70 countries. The academy is hosted at the Berlin-Brandenburg Academy of Sciences and Humanities (BBAW) in cooperation with the German National Academy of Sciences Leopoldina.

It is with great enthusiasm that the GYA endorses this report, prepared by our members to provide unique insights towards addressing issues related to the green economy and solid waste management. These issues, as identified by the international community, will play significant roles in terms of our capacity to achieve the Sustainable Development Goals. This meta-analysis and the resultant recommendations provide applicable insights for all stakeholders, from scientists, to policy makers, to industry, that we may all work together to address these mutual concerns and build a better and more sustainable world. Finally, on behalf of the GYA, we would like to thank everyone who has contributed to this effort. It has been a challenging project; the unflagging support of our collaborators and strong determination of our young authors has made this report possible. Thank you.

Co-Chairs
Mari-Vaughn Johnson and Orakanoke Phanraksa

Foreword from the Authors

Solid waste management (SWM) refers to all activities and actions required to manage waste from its inception to its final disposal. While SWM is challenging, it also has the capacity to protect the environment, improve societies' quality of life and contribute to the economy as a whole. SWM varies among countries and regions, and is considered one of the most important municipal services for a city to protect the environment, public health, and aesthetic character. Currently, the world generates about 1.3 billion tonnes of solid waste per year. This quantity is expected to increase to 2.2 billion tonnes by 2025. Improper solid waste management contributes to air pollution, surface and groundwater contamination and public health challenges. Municipal solid waste (MSW) management is commonly the largest single budget item for communities, and this sector is often one of the largest employers as well. Thus, it is imperative to move towards a green economy in the solid waste sector by prioritising waste avoidance, minimisation and promoting the "Three Rs" (Reuse, Recycle, and Recover). In addition, moving this important sector towards responsible stewardship will contribute to the main targets of the Sustainable Development Goals (SDGs): end poverty, promote prosperity and well-being for all, protect the environment and address climate change.

The United Nations Conference on Sustainable Development held in June 2012 (Rio+20) ranked a green economy as one of the major international concerns. The conference highlighted that current consumption and production methods related to economic and population growth have led to overexploitation of natural resources and seriously damaged the environment and ecosystem balance. Good environmental governance and sustainable optimisation of scarce resources are even more crucial in the current global context, which is highly vulnerable to climate change and economic and budgetary constraints.

This report provides a global snapshot of today's MSW management practices. In addition to providing details of the current situation, credible estimates are made for the potential state of SWM in 2025. This report describes the specifics of SWM in an economic context, focusing on: (1) countries with advanced economies, especially G8 countries, (2) countries in transition and with emerging economies (BRICS) and (3) countries with developing economies. It aims at motivating and assisting governments and businesses in making a transition to a green economy in the waste sector. It articulates successful public policies, business models, green investment opportunities, innovative approaches and case studies within the waste management sector. Beyond appraising the current state of solid waste management, this study ultimately proposes alternative policies and remedial action to achieve a green economy in SWM.

The InterAcademy Partnership (IAP) generously funded a Global Young Academy (GYA) project to produce this GYA policy report on „Municipal Solid Waste Management and Green Economy". IAP and GYA issued a call to their respective membership for experts in the fields of solid waste management, environmental science, green economy and sustainable development to participate in this report. Based on the response to that call, an expert workshop on "Solid Waste Management and Green Economy" was held in Halle, Germany, on 22-23 October 2015 to discuss the draft version of this report and its related case studies, and to develop key messages and recommendations for policy- and decision-makers worldwide.

The report targets decision-makers, government officials, business executives, employers, workers, consumers, researchers and the general public to improve the environmental and socioeconomic conditions of the whole globe. It aims to shape national greening of the waste sector.

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The following GYA members are thanked for giving their insights into the report: *Dr Anna Coussens, Dr Mari-Vaughn Johnson, Dr Laura Petes and Dr James Tickner*.

In order to ensure global breadth and representation, the following waste management experts from different regions of the world have contributed case studies in this report. Authors are grateful for their active participation and valuable contributions.

Name	Case Study	Organisation
Alberto Viani	The Concept of End of Waste and Recycling of Hazardous Materials	Centrum Excellence Telč and ITAM, Czech Republic
Edwin Tam	Sustainable End of Life Management for Complex Consumer Products	University of Windsor, Canada
Garth Lamb	Household Waste Management and Resource Recovery in Australia	Re. Group, Australia
Isam Janajreh	Economic Feasibility of Biodiesel Production – From Waste Cooking Oil in the UAE	Masdar Institute of Science and Technology, United Arab Emirates
John Nduko	Solid Waste Management and Green Economy in Developing Countries. A Case Study of Nairobi	Egerton University, Kenya
John Wabomba		University of Nairobi, Kenya
Karen Wilson	Waste Not Want Not: Waste as a Valuable Bio Refining Resource for Biofuels and Chemicals Production	Aston University, United Kingdom
Linda Godfrey	"Co-operatives as a Developmental Vehicle to Support Job Creation and SME Development in the South African Waste Sector –Challenges and Successes"	Council for Scientific and Industrial Research, South Africa
Matthew Eckelman	Sustainable Waste Management on an Industrial Island	Northeastern University, USA
Noble Banadda	Unlocking the Potential of Municipal Solid Waste to Meet Energy Demands for Kampala City, Uganda	Makerere University, Uganda
Paulo Heilbron	Difficulties Associated with the Justification and Optimization Principles	Brazilian Nuclear Energy Commission, Brazil
Samuel Sojinu	From the "Dirtiest "to the "Cleanest": A Multi-Faceted Approach	University of Agriculture, Abeokuta, Nigeria
Satinder Kaur Brar	Chitin and Chitosan as Natural Flocculants for Clarification and In-House Enzymes for Haze Removal in a Microbrewery	Institute National de la Recherche Scientifique Canada
Tonni Kurniawan	Greening Environment and Economy in Surabaya, Indonesia. Using Japan's Takakura Home Composting (THC) Method	Xiamen University, China
Yin Wang	A Novel Process of Sewage Sludge Hydrothermal Dewatering Combining Biochar Production	Chinese Academy of Sciences, China

Acronyms

BAU	Business as Usual
CEIT	Countries with Economies In Transition
CERs	Certified Emission Reductions
CDM	Clean Development Mechanism
CH4	Methane
CO2	Carbon Dioxide
DOC	Degradable Organic Carbon
EI	Emission Intensity
ERR	Economic Rate of Return
GDP	Gross Domestic Product
GHG	Green House Gases
HDPE	High Density Polyethylene
H2O	Water Vapour
H2S	Hydrogen Sulphide
IFC	International Finance Cooperation
MBI	Malaysian Biomass Initiative
MEA	Multilateral Environmental Agreement
MLF	Multi-Lateral Fund
MRF	Material Recycling Facility
MDG	Millennium Development Goal
MOF	Multilateral Ozone Fund
MSW	Municipal Solid Waste
NEPV	Net Economic Present Value
NGO	Non-Governmental Organisation
N2	Nitrogen
ODS	Ozone Depleting Substances
O2	Oxygen
PAYT	Pays As You Throw
PET	Polyethylene Terephthalate
PPP	Polluter Pays Principle
RD&D	Research, Development and Demonstration
SDG	Sustainable Development Goal
SISWM	Sustainable and Integrated Solid Waste Management
SME	Small and Medium-Sized Enterprise
SWM	Solid Waste Management
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UPP	User Pays Principle
U.S. EPA	United States Environmental Protection Agency
WtE	Waste to Energy

Executive Summary

This report has classified the world into three major regions: countries with advanced economies with a focus on G8 countries, transition and emerging economy countries (BRICS) and developing countries. Categorical designations were based on the GDP (Gross Domestic Product) in each nation, as well as currently adopted solid waste management practices. This report provides consolidated data on Municipal Solid Waste (MSW) quantities, composition, collection, treatment and disposal management systems by country and by region. The report also gives projections of MSW generation rates and composition for 2025 in order for decision-makers to prepare plans and budgets for MSW management in the coming years. It further explores the benefits and opportunities of greening the solid waste sector and how this can contribute to a greener economy. Finally, the report identifies the enabling conditions to greening the solid waste sector. It targets decision-makers, government officials, business executives, researchers and the general public.

MSW is a by-product of human activity. MSW, commonly called "trash" or "garbage", includes everyday items that are thrown away by homes, schools, hospitals and businesses. A burgeoning global population and the trend towards urbanisation have contributed to a rapidly increasing amount and concentration of MSW that needs to be managed. The statistics are stark: 3.5 billion people, half of the world's population, are without access to waste management services. Open dumping, with its cascade of deleterious consequences, remains the prevalent waste-disposal method in most developing countries. Urbanisation, industrialisation, a growing population and economic development all contribute to increased loads of MSW, the treatment of which is complex and potentially hazardous to people and the environment. The total amount of MSW generated globally is estimated at 1.3 billion tonnes per year and is expected to increase to approximately 2.2 billion tonnes by 2025 (Hoornweg and Bhada-Tata, 2012). There is a direct proportional relation between a nation's gross domestic product (GDP) and the amount of MSW generated per capita. The higher a nation's GDP is, the greater the amount of solid waste each individual generates. Regardless of the level of national development, MSW management is one of the most important services a city both needs and provides. Poor management of MSW can have significant impacts on human and animal health, local and global environmental sustainability and the economy. It is best to treat MSW properly and in a timely manner, thus avoiding social, economic and ecological impacts. The cost of remediating improperly managed MSW tends to be more expensive than the cost to manage the waste properly in the first place.

The Heads of 193 States and Governments met at the United Nations Headquarters in New York from 25 to 27 September 2015 and agreed on new global Sustainable Development Goals (SDGs). As part of the main outcome, they adopted the document, "Transforming our world: the 2030 Agenda for Sustainable Development", which stated that managing the solid waste sector has the potential to contribute to job creation, mitigate environmental and health impacts and improve the whole nation's economy. This leads to "**greening**" the solid waste. **Greening** the MSW sector will contribute to achieving the Sustainable Development Goals (SDGs), especially the following out of the announced 17 goals:

- **Goal 1** – No Poverty;
- **Goal 3** – Good Health and Well-Being;
- **Goal 7** – Affordable and Clean Energy;
- **Goal 8** – Decent Work and Economic Growth;
- **Goal 11** – Sustainable Cities and Communities;
- **Goal 12** – Ensure Sustainable Consumption and Production Patterns;
- **Goal 13** – Climate Action by mitigating the GHGs; and
- **Goal 17** – Global Partnership for Sustainable Development by addressing the needs of the developing countries through non-discriminatory international funds (i.e. international donors' involvement).

There is no one-size-fits-all model when it comes to greening the MSW sector, but there are commonalities across countries that could help inform its sustainable development. As a common feature, strategies for greening the MSW sector generally include an emphasis on the minimisation or prevention of waste, followed by effective application of the "three Rs": reuse, recycle, and recover. Prevention and reduction of waste at generation source should be a high priority for all countries. This goal is particularly important in developing countries, given their higher level of population growth and increasing material and resource consumption. Increased access to new technologies provides communities with new opportunities to green the MSW sector. Greening the MSW sector entails a move away from Business as Usual (BAU) practices to an ecologically and economically viable approach that seeks positive direct and indirect economic benefits. There is a need to change the mind-set that considers MSW a liability towards a realisation that MSW is a potential resource for generating economic activities and creating jobs, while improving the environment and human welfare. Emerging and developing economies, in particular, have a significant opportunity to benefit from greening the SWM; they should develop their own visions and long- and short-term strategies for greening the SWM sector in order to generate multiple economic and ecological benefits, including, but not limited to: ***savings in energy and natural resources; job creation and new business opportunities; production of compost for agriculture; production of energy from waste; GHG emissions reduction; poverty reduction; and improved health and reduced health costs.***

This report sets several recommended actions to be taken into consideration in both short and long terms, especially for emerging and developing economies. These recommendations will aid to greening the waste as well as achieving the main SDGs related to the waste sector. These actions are:

- Create platforms where different stakeholders can meet and learn in collaboration both informally and formally in regular annual meetings. Such platforms are needed both inside and outside the formal educational system. Enhancement of public participation and consultation would be effective in advancing SWM practices.

- Governments must ensure the development of comprehensive, clear environmental policies addressing municipal solid waste management. Governments should be committed to their implementation nationwide in order to turn towards green economy in the waste sector. Policies and regulations such as targets for the minimisation, reuse, recycling and displacement of virgin materials in products, regulations relevant to the waste management market and land-use policies and planning and regulations to set minimum safety standards that protect labour are crucial. The report includes several case studies from different countries and regions to provide insights on relevant policies and ongoing initiatives.

- The formalisation of the currently informal scavenger sector prevalent in many countries is a priority. Such formalisation has the potential to ensure proper working conditions and labour standards for all workers in the SWM sector, including scavengers. Moreover, policies should also improve labour conditions in the informal waste sector to avoid severe health and socioeconomic impacts. Further, scavengers and their supervisors require education and training regarding safety standards and health protection, which could be carried out by governmental and non-governmental organizations (NGOs).

- Establish comprehensive, integrated, harmonious plans at sectorial and geographical levels in accordance with the 3Rs (Reduce, Reuse and Recycle). The 3Rs should be promoted. The report identified great potential for resource recovery in developing countries, which could be realized with better public awareness and initiatives by local bodies and communities.

- Conduct a package of tools for enforcement and compliance: legal, economic, communication and outreach tools. In addition, strengthening the capacity of local bodies is essential, as they are mandated to provide SWM services to the citizens.

- Current poor management practices such as open dumping and open burning should be stopped immediately to allow for more integrated SWM.

- Conduct mechanisms and programs for finance, financial support and technical support. Governments should formulate some incentives to encourage moving towards greening the solid waste sector.

These incentives can be used to change behaviour and to correct price distortions in the market. The incentives in the waste sector include: 1) taxes and fees; 2) recycling credit and other forms of subsidies; 3) deposit – refund, and 4) standards and performance bond or environmental guarantee fund.

- Accelerate innovation to meet our shared, long-term SDGs through the contribution of technological innovation to fostering economic growth. There is a need to incentivise investments in safe and sustainable waste treatment technologies, using a range of available policy options such as policies to support research, development, and demonstration (RD&D).

- Conduct further research and studies in each region to identify the health damage costs and benefits in the solid waste sector. The potential of health benefits as a result of greening the municipal solid waste should be studied thoroughly as a significant socioeconomic positive impact on the affected societies by this solid waste sector. Hence, alleviating severe health issues, such as HIV and hepatitis, will be a significant economic added value for communities.

Key Messages

1. The increase of solid waste associated with economic growth poses serious risks to ecosystems and human health.

MSW is one of the by-products of human activity, and increasing population and urbanisation is resulting in a rapid increase to the volume and complexity of MSW that needs to be managed. The total amount of MSW generated globally is estimated at about 1.3 billion tonnes per year, which is expected to increase to approximately 2.2 billion tonnes by 2025. There is a strong positive correlation between a nation's gross domestic product (GDP) and the solid waste generation by its citizens: as GDP increases, so does the per capita generation of solid waste. The biodegradable portion of solid waste contributes approximately 5% of GHG emissions in the last decade. Electrical and electronic equipment waste, sometimes called "e-waste", often contains complex, hazardous substances which may have deleterious impacts on human health and the environment. Hospital and veterinary waste can include substances with significant implications for ecological, animal, and human health impacts. While there are differences in waste composition and per capita volumes between low-income countries and high-income countries, a common truth is that the appropriate management of MSW is one of the most important considerations for any city.

2. Greening the waste sector requires financing, economic instruments, policy and regulatory measures, and institutional arrangements.

Encouraging decision-makers to prepare plans and budgets for a proper transition to the green economy in the solid waste management sector is crucial. Economic regulations and policy tools in advanced countries have forced and, at the same time, enabled municipalities to develop and adopt technologies for recovering resources from MSW. For example, some governments use an approach that allows the market to set tipping fees that reflect actual costs, coupled with added public awareness campaigns and enforcement against dumping. Municipal planners should manage solid waste as holistically as possible. Greening the MSW sector will support the economies of developed, BRICS and developing countries. Cost recovery from improved waste management can help reduce the financial burden on governments. In addition, private sector participation can reduce costs, enhance service delivery, and provide benefits to the economy. Finally, a range of economic instruments can serve as incentives to green the MSW sector. The cooperation of international donors (i.e. World Bank and United Nations) will encourage governments and policy-makers to move towards greening the waste sector. This might improve the global partnership for development, one of the targets of the SDGs (Goal 17).

3. There is no one-size-fits-all approach when it comes to greening the waste sector.

It is crucial that emerging and developing countries carefully consider the appropriateness of alternative waste treatment technologies, so that they don't get locked into technologies which may be more appropriate for developed countries. Also, there is a good opportunity to learn from the mistakes and successes of other nations. Opportunistic resource recovery, both through formal approaches and informal scavenging, can have a significant impact on overall MSW programming. The effective integration of scavengers, particularly in low-income countries, is critical to a successful greening effort. A common feature did emerge: greening the SWM sector necessarily includes the minimisation or prevention of waste production and promotion of the "three Rs" (reuse, recycle, and recover).

Waste management is a diverse issue. However, this report reaches the consensus that effective MSW management should follow the typical solid waste management hierarchy, support livelihoods, protect human and ecosystem health, and reflect actual costs.

4. Increasing resource scarcity and the availability of new technologies offer opportunities for greening the waste sector.

Greening the waste sector entails a move from business as usual practices to an economically and ecologically viable approach that seeks positive direct and indirect economic benefits.

Reuse, recycling, and energy recovery are considered viable approaches that can contribute to greening while also generating income and promoting innovation. There is a need to change the mind-set that considers solid waste a liability and develop a mind-set and vocabulary around MSW as a potential resource for generating economic activities, diversifying risk, creating jobs and improving the environment and human welfare. In order to shift the paradigm, long-term waste management and investment strategies, specific to each local municipality/region, are needed. The long-term waste management strategy should cultivate a new culture that advocates the integration of waste avoidance, minimisation, recycling, reuse, and recovery in sectorial and macroeconomic policies.

5. Greening the waste sector generates multiple economic benefits.

Greening the waste sector can significantly contribute to the creation of new jobs, mitigate environmental and health impacts and improve the economy as a whole. The management of MSW is commonly the largest single budget item for cities and often one of the largest sectors of employment. Poorly managed waste has significant impacts on health, as well as on the local environment and the global environment (e.g. greenhouse gases emissions, water quality, soil health, biodiversity). Improperly managed waste commonly results in the necessity of adopting higher cost solutions (i.e. remediation) as compared to the solutions that could manage the waste properly. Greening the waste sector therefore has the potential to improve the economy as a whole. These benefits will contribute to or achieve the SDG goals, especially: 1) Goal 1 –No Poverty; 2) Goal 3 –Good Health and Well-Being; 3) Goal 7 – Affordable and Clean Energy; 4) Goal 8 – Decent Work and Economic Growth; 5) Goal 11 –Sustainable Cities and Communities; 6) Goal 13 –Climate Action by mitigating the GHGs; and 7) Goal 17 – Global Partnership for Sustainable Development by addressing the needs of the developing countries through non-discriminatory international funds (i.e. international donors involvement).

6. Upcycling creates more jobs than it replaces.

Upcycling is the creative modification of discarded objects in such a way to create new product of higher quality or value towards the upper end of the innovation scale. Upcycling can create job opportunities more than land filling or incineration on a per tonne basis. Greening the waste sector and following an appropriate MSW management approach can lead to employment generation where more employees will be required to successfully maintain a new management system. This approach benefits Goal 1 of the SDGs: No Poverty, by generating more jobs.

7. Improving labour conditions in the informal waste sector is imperative.

In developing countries, the activities of collection, processing and redistribution of solid waste are usually done by scavengers with poor facilities and little training or education regarding the risks associated with their jobs, which include significant potential health impacts (i.e. HIV and hepatitis), which result in socioeconomic issues. Thus improving the labour conditions in the solid waste sector is vital and can be achieved by several means, including the prohibition of child labour, the provision of personal protection equipment (i.e., gloves, safety shoes, protective clothes) and the provision of trainings and workshops to raise worker and society awareness of risks and possible solutions. Hence, the current prevalence of severe diseases associated with unhealthy working conditions in the SWM sectors of many countries can be alleviated by improving labour conditions, which contributes to Goals 3 and 8 of the SDGs: Good Health & Well-Being and Decent Work & Economic Growth.

8. There is an imperative to accelerate widespread innovation in a full range of safe and sustainable waste management.

Accelerating innovation is vital to meet our shared, long-term SDGs. We acknowledge the contributions of technological innovation and access to such innovation towards fostering economic growth. This report also demonstrates the need to incentivise investments in safe and sustainable waste treatment technologies, using a range of available policy options such as policies to support research, development, and demonstration (RD&D).

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0. Front Matter

1. Introduction

A number of major simultaneous crises have emerged during the last decade, including those related to climate, biodiversity, fuel, food and water. Together, these issues impede the global community's ability to sustain prosperity and achieve the Millennium Development Goals (MDGs), which were developed at the 2002 World Summit in Johannesburg. These crises also contribute to negative social impacts, including unemployment, socio-economic insecurity, poverty and social instability (UNEP, 2011).

The MDGs developed in 2002 were a UN initiative that targeted ending poverty, promoting prosperity and well-being for all, protecting the environment and addressing climate change with eight targets to be achieved by 2015(UN, 2015a). The year 2015 was a milestone for global action to set the post-2015 Sustainable Development Goals (SDGs). The transition from the MDGs to the SDGs seeks to advance prosperity, secure the planet's sustainability for future generations, and unlock resources for investments in education, health, equitable growth and sustainable production and consumption. There are 17 goals each of which has specific targets to be achieved over the next 15 years (UN, 2015 b).

Sustainable Development Goals (UN, 2015c):

1. No poverty
2. Zero Hunger
3. Good Health and Well Being
4. Quality Education
5. Gender Equality
6. Clean Water and Sanitation
7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry, Innovation, and Infrastructure
10. Reduced Inequalities
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate Action
14. Life Below Water
15. Life on Land
16. Peace, Justice and Strong Institutions
17. Partnerships for the Goals

Waste generation is an integral part of modern human activity. Solid waste streams can be characterized in a variety of ways: by source, original use, or physical and chemical composition. Some types of solid waste are usually managed by industry that generates the waste, such as industrial wastes, agricultural wastes, and mining wastes. The wastes that are managed by municipalities, including those generated by individual households, are called municipal solid waste (MSW). This report focuses on the management of MSW.

The quantity and composition of MSW is influenced by a variety of factors, but depends mainly on the population and GDP per capita. The significant and continuing increase in MSW generation over recent decades is partially due to the combined impacts of rising global population and per capita GDP, and it is an indicator of natural resource depletion.

The process of greening any sector has been defined as "the process of configuring businesses and infrastructure to deliver better returns on natural, human, and economic capital investments, while at the same time reducing greenhouse gas emissions, extracting and using less natural resources, creating less waste, and reducing social disparities" (Gueye, 2010). Solid waste management will contribute to job creation, mitigate environmental and health impacts, and improve the whole nation's economy. This can be defined as "greening the solid waste sector".

Greening the solid waste sector has the potential to make significant contributions to the SDGs and green growth through reduction of waste, conservation and efficient use of material and energy, lower emissions, protection of human health and creation of jobs and employment opportunities.

Figure 1: General Waste Hierarchy According to EU Waste Framework Directive (ISWA, 2013)

Greening the solid waste sector could contribute to the following goals and targets of the SDGs:

1. No Poverty (Goal 1): by achieving full and productive employment and decent work for all MSW sector workers, including women and young people.
2. Good Health and Well-Being (Goal 3) and Decent Work and Economic Growth (Goal 8): by improving the labour conditions and working environment for workers in the MSW sector. In addition, proper waste management leads to healthy water and food, which in turn enhances the health of human beings.
3. Affordable and Clean Energy (Goal 7) and Sustainable Cities and Communities (Goal 11): by integrating the principles of sustainable development into country's policies and programs. Greening the MSW sector will also reverse the loss of environmental resources by following the solid waste hierarchy and encouraging the concept of the three Rs: Reuse, Recycle, and Recover.
4. Responsible Consumption and Production Patterns (Goal 12): by substantially reducing waste generation through prevention, reduction, recycling and reuse
5. Climate Action (Goal 13): by taking actions to reduce GHGs in the solid waste sector and its impacts.
6. Partnership for the Goals (Goal 17): by providing international funding, new technologies and information & communications to private and governmental sectors in developing countries.

Thus far, the world's nations have not capitalised on the opportunities inherent in the development of a green SWM sector. In particular, developing countries have ample potential to improve the greening of their MSW sectors and to enjoy the impact of the greening on their communities and economy. At present, in developing countries very little emphasis is currently placed on sustainable management of solid waste. Examples from several countries demonstrate cases of successful greening of the MSW sector under varied contexts and circumstances. The appropriate course of action and policy, technological and instruments applied in institutional interventions instruments vary among countries depending on the different stages of economic development and the associated state of solid waste generation and management. *Figure 1* shows the general SWM hierarchy according to the EU Waste Framework Directive.

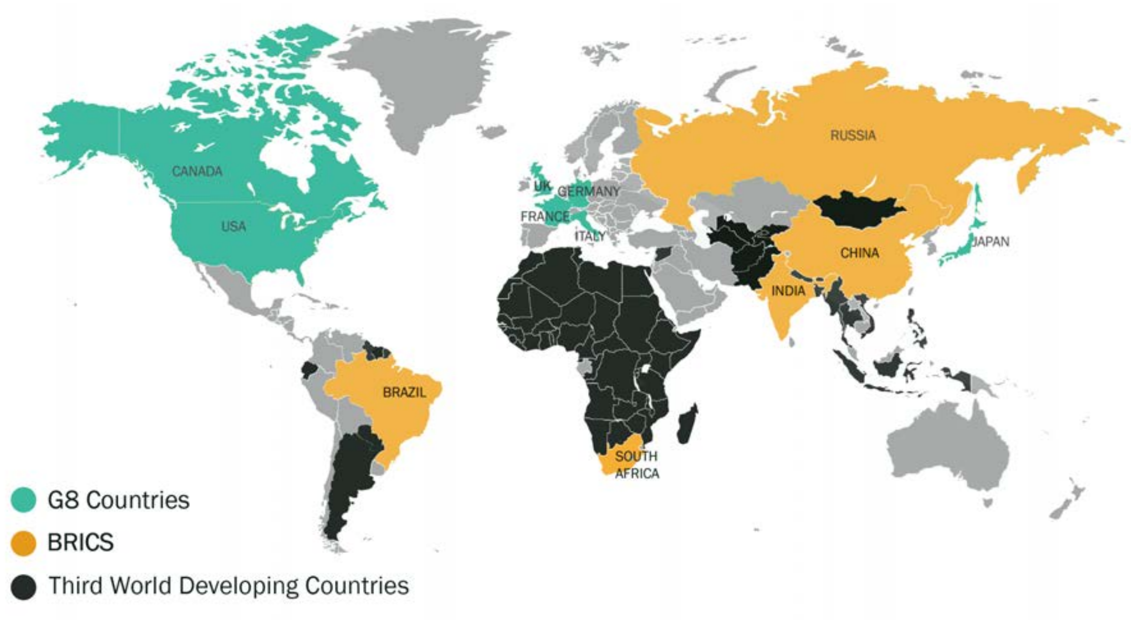


Figure 2: G8, BRICS, and Developing Countries Illustrative Map (Samake and Yang, 2014; Marshall, 2005)

A green economy is characterised by public and private investments that result in improved economic returns, a healthier environment, and social development. Policies in green economies are often formulated to stimulate investment in green initiatives. Thus, making the transition to a green economy requires a political environment that holds the long-term wellbeing of individuals and sustainable business model as the highest priority and manages resources as assets for future generations.

A successful solid waste management plan requires a systems approach rather than disjointed individual attempts. Societies need to evaluate, in a holistic and integrated manner, the combination of components that can maximize economic, environmental, and social benefits at a reasonable cost for current and future MSW generation, which has been defined by “Greening the Waste Sector”. This holistic solid waste management approach or strategy involves prioritising waste avoidance and minimisation, practising segregation and solid waste management services, promoting the “Three Rs” (Reuse, Recycle, and Recover), implementing safe waste transportation, treatment, GHG emissions mitigation and operating safe disposal facilities. Stakeholder involvement should adopt a certain systems approach that should be economically viable and driven by developing sustainable technologies and creating jobs. Proper MSW management helps to preserve the ecosystem, improve the quality of the surrounding environment (i.e. air, water, soil) and mitigate negative health impacts.

This report has divided the world in three major regions: countries with advanced economies, specifically G8 countries, transition and emerging economy countries (BRICS) and developing economies. The G8 is a forum of eight countries whose size or strategic importance gives them a particularly crucial role in the global economy. G8 countries were chosen to represent the developed countries in this study thanks to their advanced economies and high income and GDP. G8 countries include: Canada, France, Germany, Italy, Japan, Russia, the UK and the USA (Marshall, 2005) The BRICS are the emerging economies countries (medium income) and they are Brazil, Russia, India, China and South Africa (Samake and Yang, 2014). *Figure 2* shows an illustrative map for the three different economic standards regions.

This report provides a summary of knowledge on current MSW quantities, composition and management practices in the different regions, namely G8, BRICS, and developing countries. It is a desk-top assessment study and review of existing knowledge available from relevant literature employing various documentary/secondary sources including IPCC, the UN, US EPA, the EU and others. The study relied mainly on case studies from various parts of the world to capture diversity of contexts, stage of development and states of solid waste and management strategies and practices.

The report also discusses the benefits of greening the waste sector, including mitigation options to reduce GHG emissions and recover materials, energy production from solid wastes, job creation and the impact on human well-being. The report explains the opportunities, cost related to greening waste sector, barriers to be faced and the enabling conditions that can facilitate moving towards more sustainable waste management systems. It shows case studies from the three regions of the world supporting all ideas generated. The focus of this report is to motivate and assist governments and businesses worldwide to make a transition to the green economy in the municipal solid waste management sector. The study of global solid waste management models and examining how it shaped public policies, business models, green investment opportunities and innovative approaches is of paramount importance to influence decision-makers towards green economy. Examining lessons, learning from successful case studies and solid waste management policies and models in G8, BRICS, and developing economies provides the basis on which one can support the shifting to green economy.

In the next section, the report will show the state of waste followed by a section about unlocking the opportunities of the MSW sector. Section 3 will depict the opportunities for greening the waste, upcycling in green economy, the cost of greening waste sector and the barriers to realising green economy. Section 4 presents the enabling conditions to green the waste sector, including economic instruments, costing and financing, human resource development and monitoring and evaluation. Finally, a summary is presented in Section 5, together with the authors' recommendations.

2. State of Municipal Solid Waste

2.1. Source and Quantities of Municipal Solid Waste

The total amount of MSW generated globally is estimated at about 1,300 million tonnes per year, and it is expected to increase to approximately 2,200 million tonnes by 2025 as shown in *Figure 3* (Hoornweg and Bhada-Tata, 2012). The major sources of MSW are the residential and commercial sectors (*Figure 4*; Mihelcic and Zimmerman, 2010). The quantities of food wastes, garden wastes, paper, plastic and glass generated from both sectors contribute most to solid waste overall. Then the waste quantities vary among the remaining sectors, with construction and demolition having the highest contribution percentage after the residential and commercial sectors. This is due to the generation of concrete, metal, wood, asphalt, wallboard and dirt-predominant wastes.

2.1.1 Municipal Solid Waste Characterization

The characterisation of MSW is a complicated task because it varies greatly in composition and quantities within a region, and over time. Estimates of solid waste composition are always uncertain. Three methods are commonly used to identify the solid waste characteristics: literature review, input-output analysis and sampling surveys. In 2006, the U.S. EPA identified the percentage of various materials that compose MSW on a mass basis (*Figure 5*). Although it is known that organic waste comprises the largest share of MSW in most countries, paper and cardboard has the largest share on a mass basis. This is followed by garden wastes, food, plastics and other constituents.

A shift from high organics to higher plastic and paper corresponding to the increase in GDP can be concluded from the MSW typical composition by region based on the income levels and economic standards (*Figure 6*).

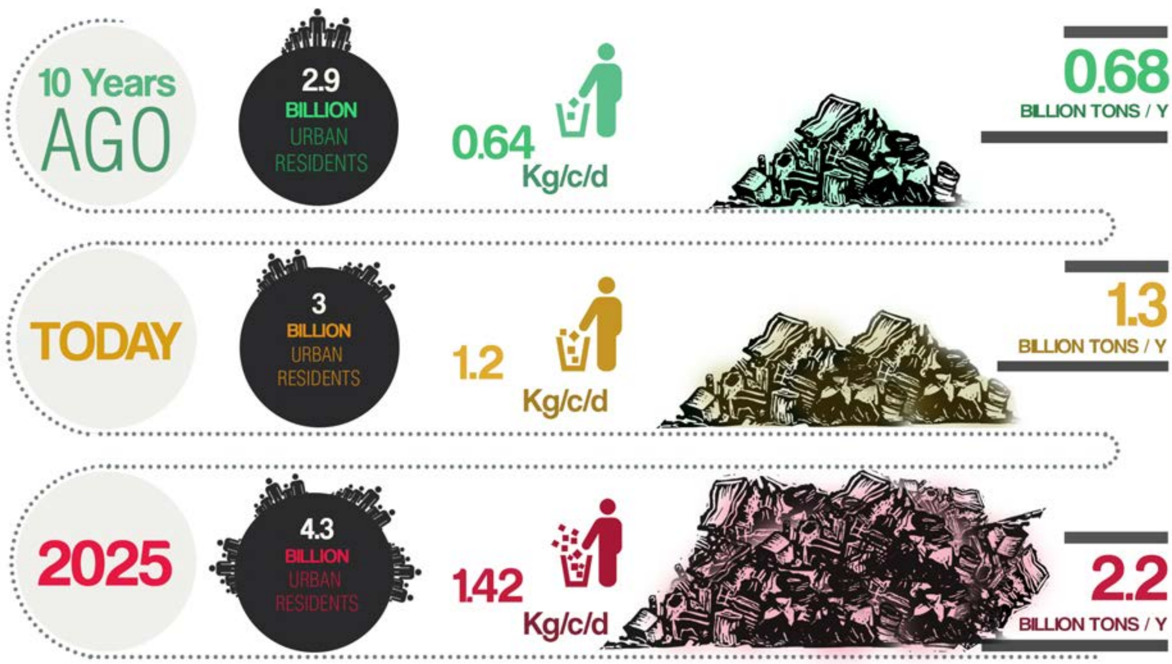


Figure 3: Municipal Solid Waste Quantities (Hoornweg and Bhada-Tata, 2012)

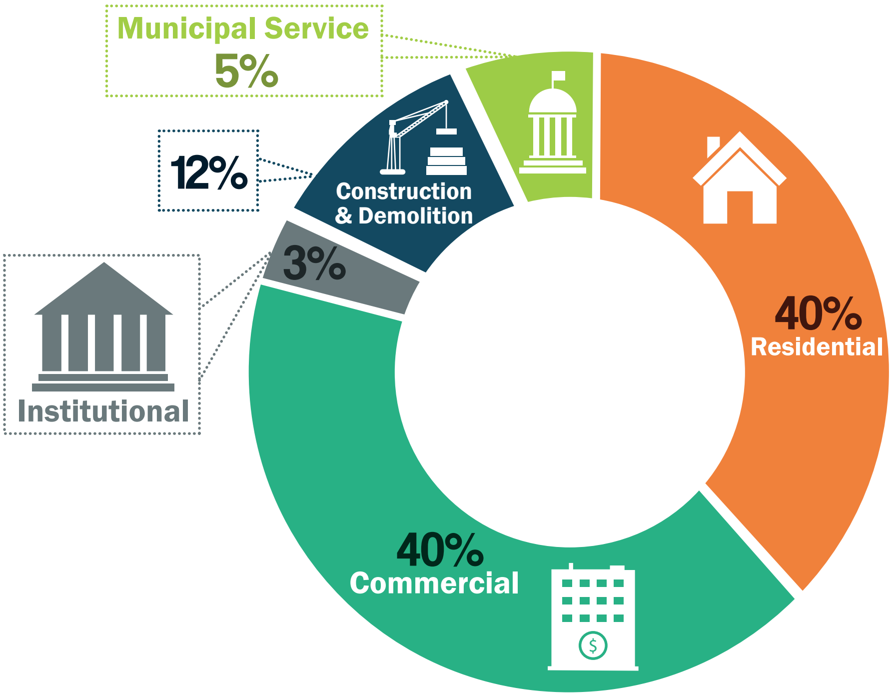


Figure 4: Municipal Solid Waste Source (Mihelcic and Zimmerman, 2010)

On the other hand, it is worth mentioning that higher-income households in developing countries tend to generate more inorganic waste, while low-income households produce a greater fraction of organic material. However, some high-income households in developing countries still generate the same amount of organic waste as standard households in low-income countries do.

Affluence is a strong driver of MSW generation. The solid waste generation rate in developing countries and BRICS in 2012 was lower than in G8 countries (*Figure 7*). (World Fact Book, 2015; EEA, 2015; IPCC 2006).

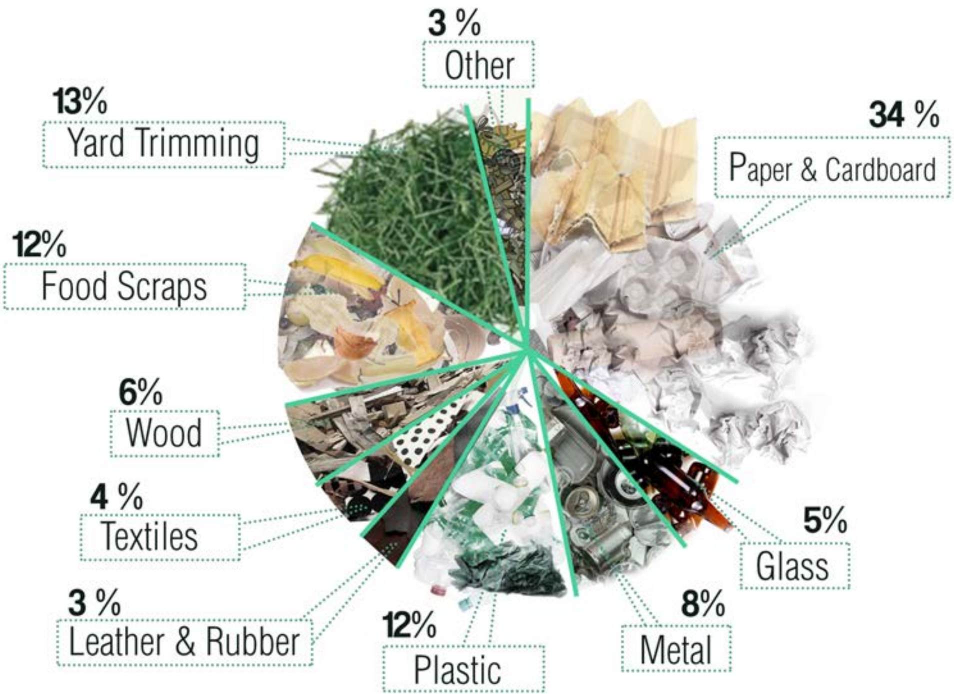


Figure 5: Percentage of Various Materials that Compose MSW on a Mass Basis (U.S. EPA, 2006b)

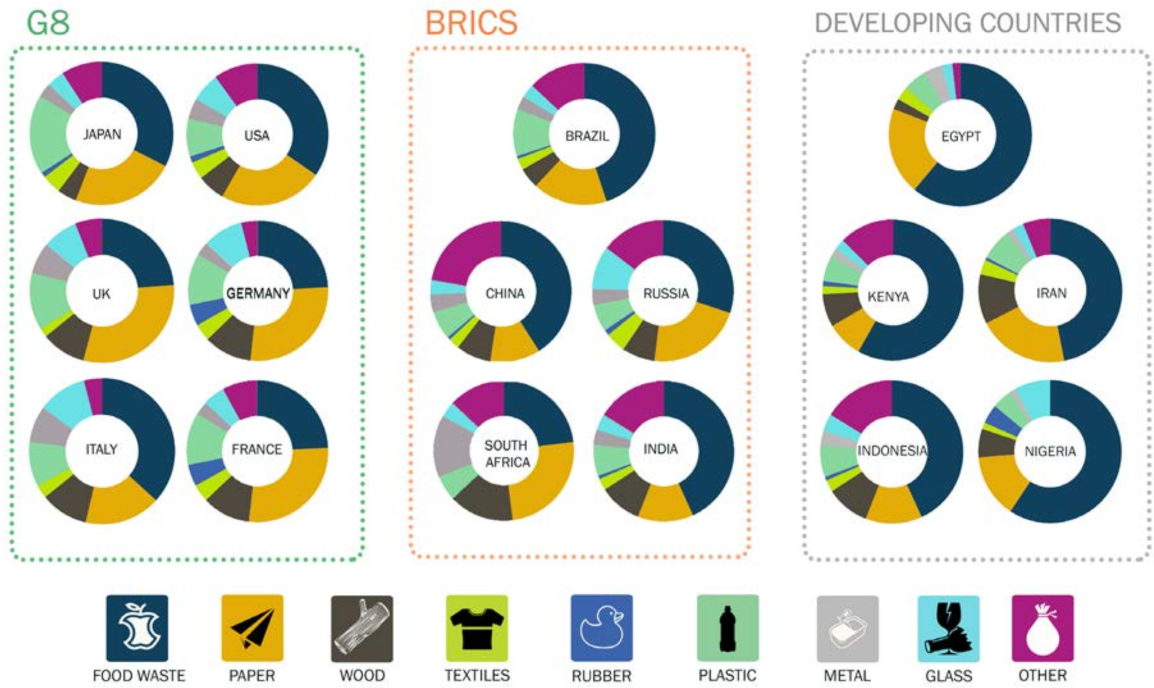


Figure 6: Municipal Waste Composition by Region and Country (Zero waste, 2012; EEA 2013a; EEA 2013b; Ayuba 2013; EASA, 2012; IPCC, 2006)

The projection of MSW generation rate in the year 2025 for some countries within the three targeted regions (G8, BRICS, and developing countries) is provided in Figure 8. It is obvious that the waste generation rate will increase slightly in some of the G8 countries while in some other G8 countries, such as Japan, Germany and Italy, it will remain the same or decrease. This can be attributed to low population growth rate, increased awareness and policy interventions addressing waste management. For example, EU regulations have stimulated recycling

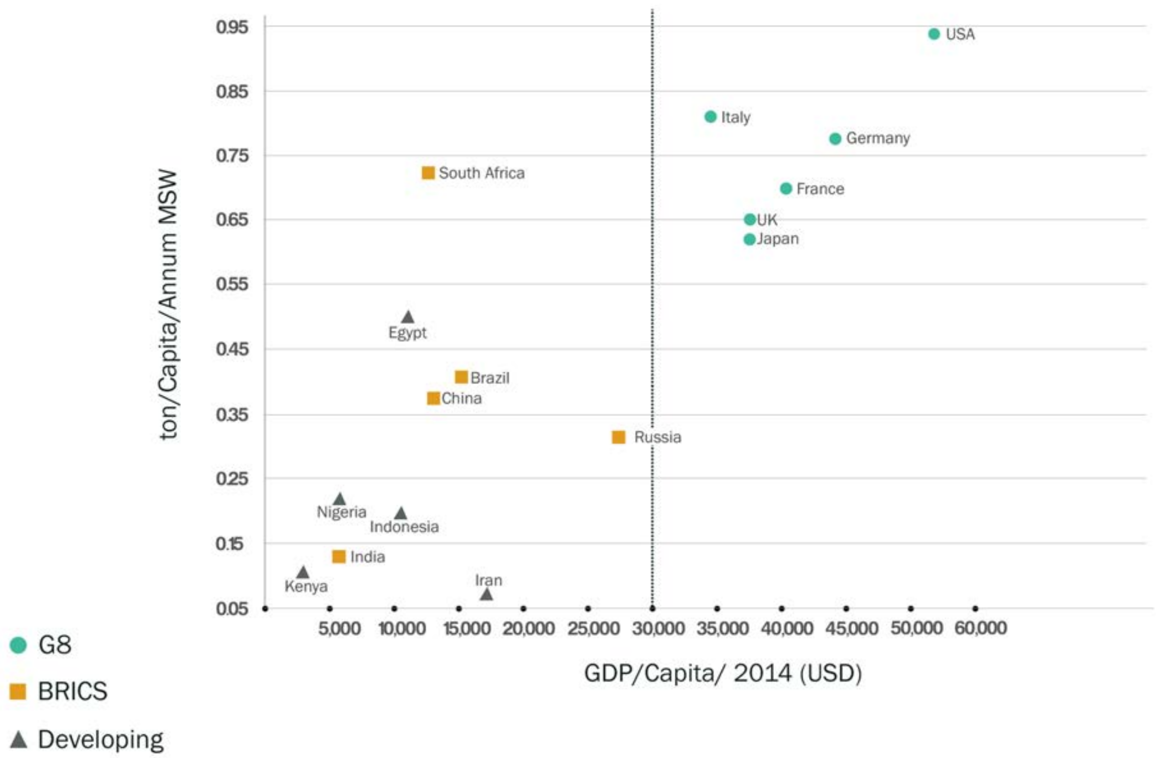


Figure 7: MSW Generation and GDP per Capita for Different Countries Worldwide in 2012 (G8, BRICS, and Developing Countries) (World Fact Book, 2015; EEA, 2015; Hoornweg and Bhada-Tata, 2012)

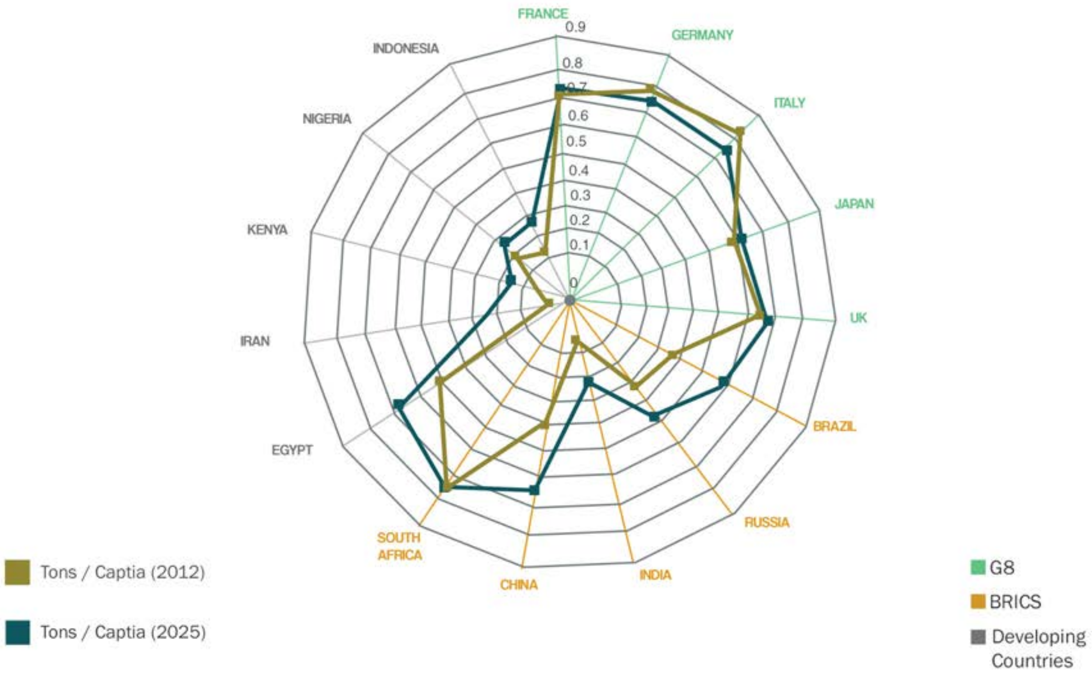


Figure 8: MSW Projection by Country (tonnes/capita) for 2025 (Hoornweg and Bhada-Tata, 2012)

of obsolete vehicles since 2000 and electrical and electronic waste since 2002 (UNEP, 2011). On the other hand, the MSW generation rate in both BRICS and developing countries is expected to increase rapidly by 2025, except for South Africa. The latter might be attributable to increasing public awareness in South Africa and conducting some policy and economic drivers, such as cooperatives. The projection of MSW generation rate triggers a toll for the developing countries especially to promptly adopt proper MSW management practices.

2.1.2 Solid Waste Management Practices

Progress in technologies for converting wastes into energy, gasification, and more developed recycling mechanisms are moving forward to the realisation of a mixture of products along with achievement of higher levels of efficiency and sustainability. It should be noted that, while the waste hierarchy adequately describes the general options for developed countries, some of them are yet to transition to the use of an engineered landfill (consider the 'last resort' in developed countries), and that properly designed landfills can present a significant improvement compared with uncontrolled dumping of waste in non-sanitary landfills. *Figure 9* shows the development of MSW Treatment and Disposal. Most advanced countries reached stage 4 or 5 of the development process. Most developing countries are still at stage 2.

Figure 10 presents the share of different MSW management practices in several nations. More than half of the globally generated MSW is dumped or disposed in non-sanitary landfills. Recycling of MSW is used to manage only approximately 20% of the total generated waste. The remaining solid waste quantities are used for energy recovery (WtE). In the developed countries, the option of landfilling is on the decrease over time compared to the other options, as depicted in *Figure 11*. This might be attributed to the low availability of land and higher community expectations around the appropriate management of secondary resources.

Figure 12 illustrates the MSW generation rate and the percentage disposed, incinerated, composted and unspecified in the three different regions. The sharp decrease in the portion of MSW to be landfilled in G8 countries may be attributable to increased awareness and policy interventions addressing waste management (for example, the EU Landfill Directive [1999/31/EC], which obliges Member States to reduce the amount of biodegradable MSW being landfilled). The fraction of unspecified MSW management is higher in the developing countries.

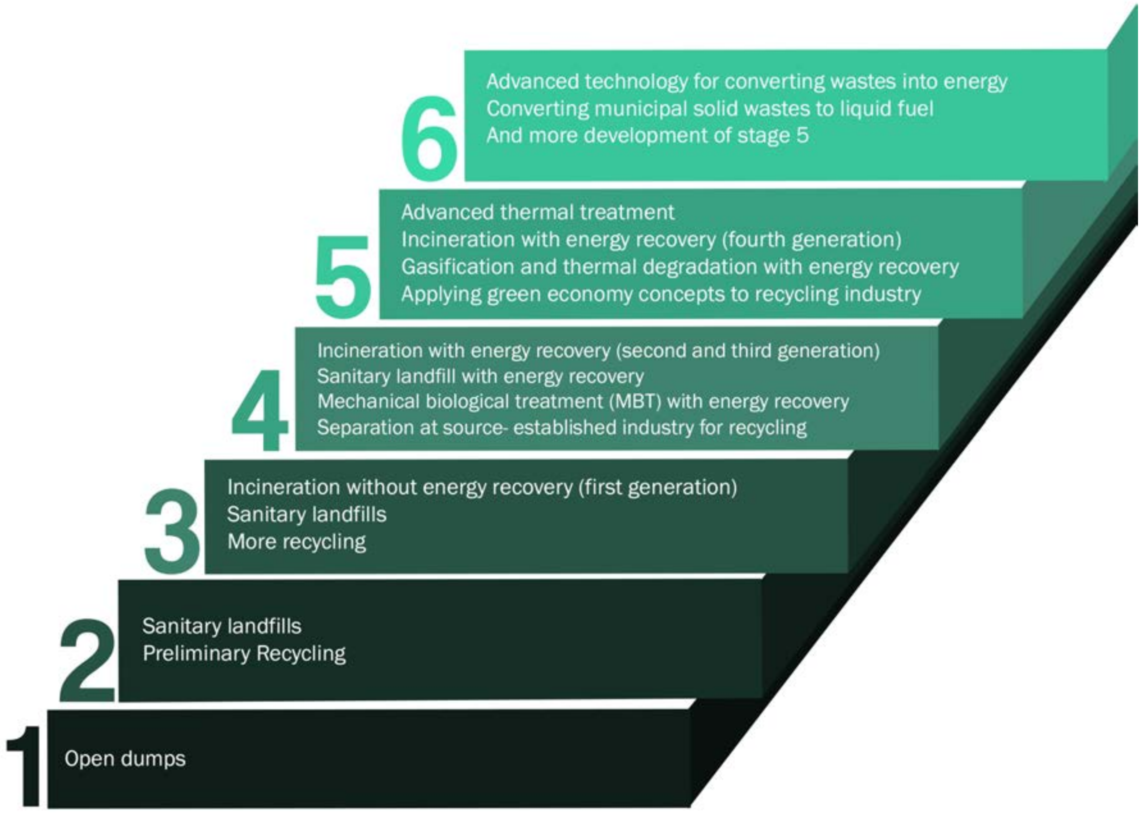


Figure 9: Development of MSW Treatment and Disposal (Gaber, 2014)

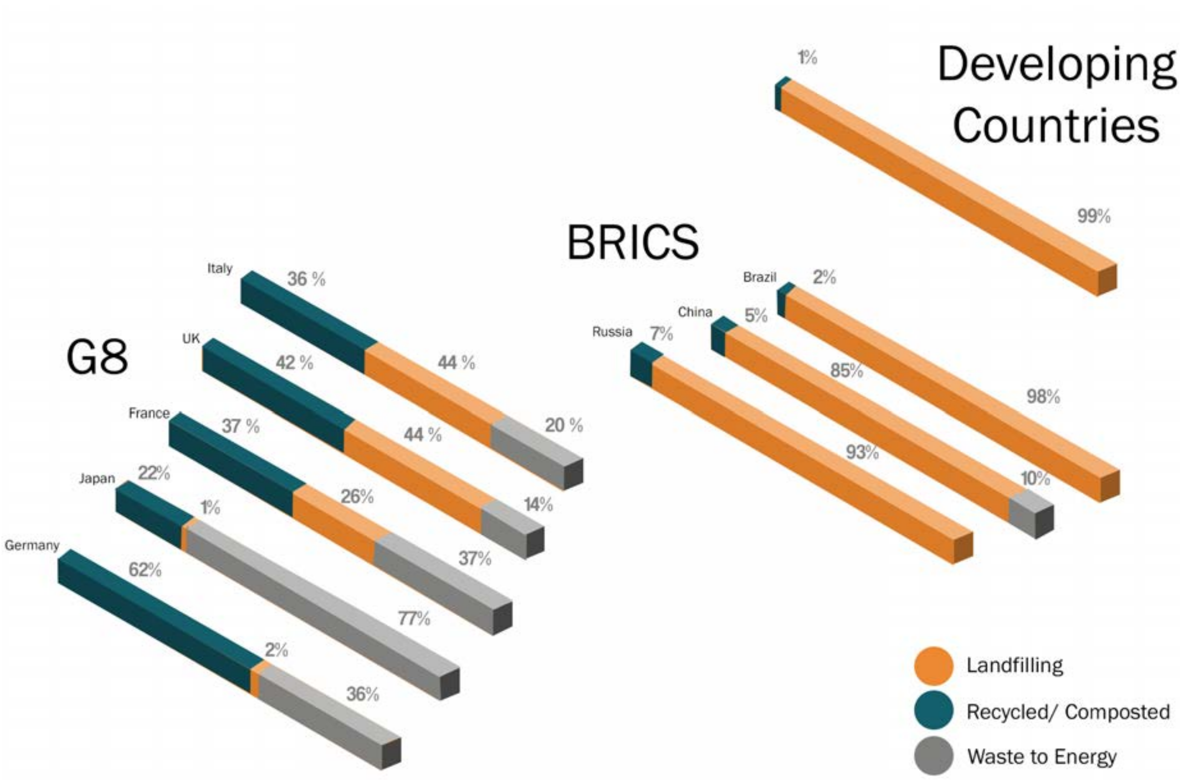


Figure 10: Management Practices of MSW (Fischedick et. al., 2014)

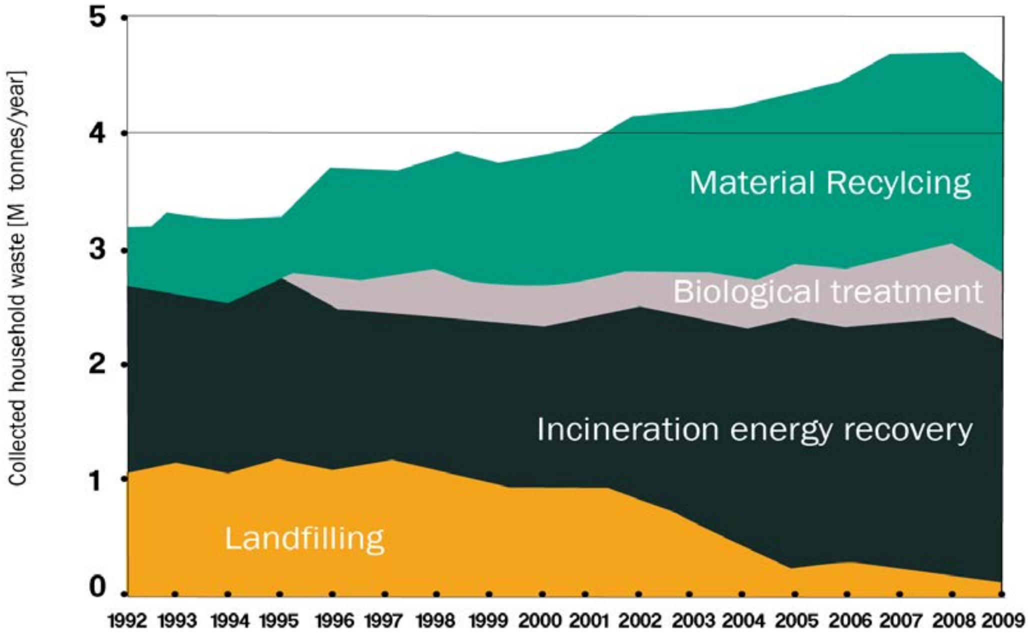


Figure 11: Municipal Solid Waste Strategy Approach in Developed Countries over Time (Finnveden et.al., 2013)

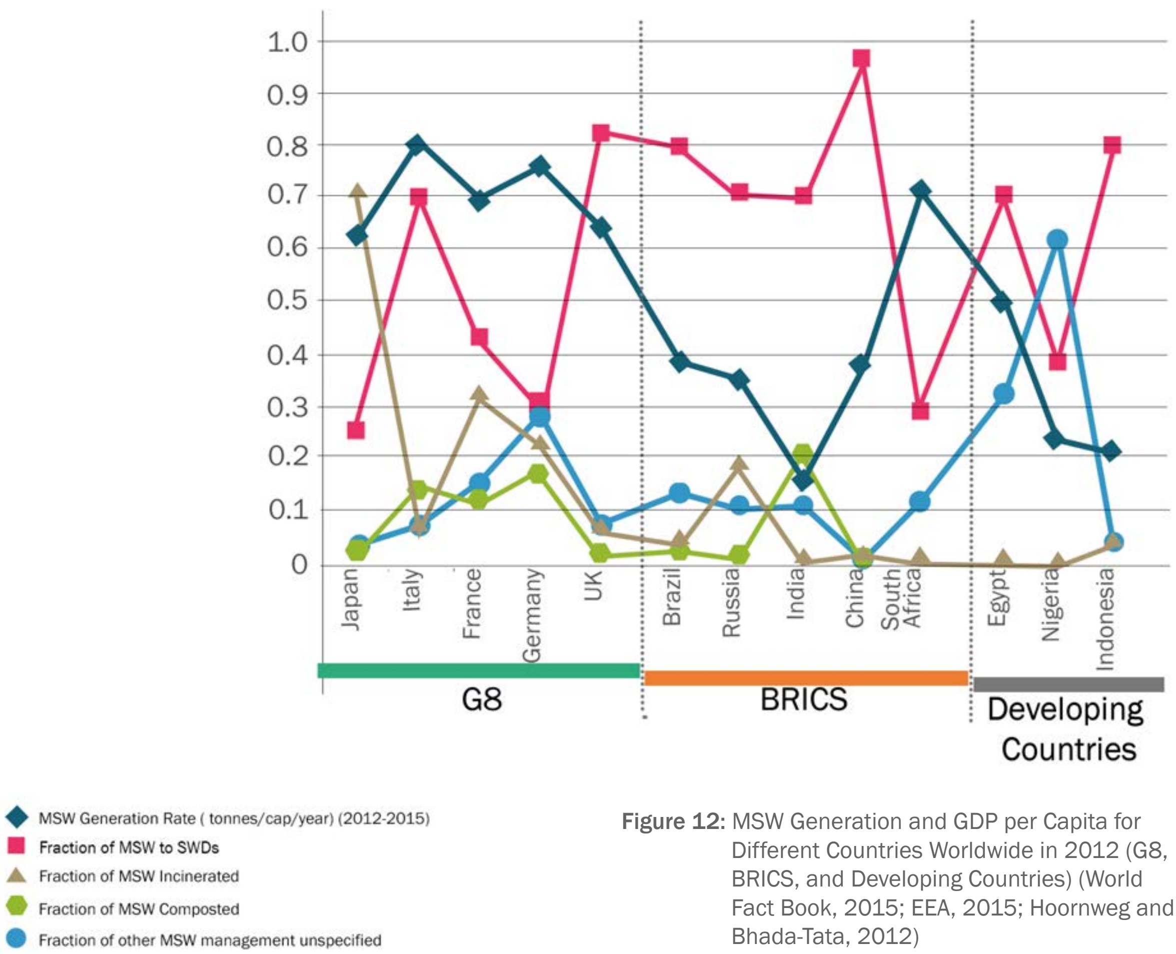


Figure 12: MSW Generation and GDP per Capita for Different Countries Worldwide in 2012 (G8, BRICS, and Developing Countries) (World Fact Book, 2015; EEA, 2015; Hoornweg and Bhada-Tata, 2012)

3. Unlocking The Opportunities Of MSW Sector

3.1. Introduction

Greening the solid waste sector will provide major benefits to societies and will significantly contribute to the indirect economic indicators in terms of employment generation, GHG emission reduction and its associated health benefits, enabling energy production, and protecting human health.

3.1.1 Green Economy

> **"Green Economy"** is based on the model of sustainable development and the principles of ecological economics. "Green Economy" has no internationally agreed definition, but the UNEP interpretation is widely used: "an economy that results in improved human well-being and reduced inequalities over the long term, while not exposing future generations to significant environmental risks and ecological scarcities" (UNEP, 2010).

Greening the solid waste sector will require a shift from the conventional solid waste management practices (which focus mainly on protecting human health) to the promotion of waste avoidance reduction, reuse, recycling and recovery, which can better protect human health while also creating economic activity and addressing global resource depletion. This shift can be achieved through the application of sustainable and integrated solid waste management approaches that create job opportunities, generate energy and other by-products for beneficial use and improve the quality of life and health, which increases the value of physical assets. Investments in solid waste management can enrich the economy by introducing new services, products and systems in other sectors, including industry, agriculture, manufacturing, construction, transportation and processing. Modern investment opportunities are in recycling, composting, transportation and energy production (Abaza, 2014).

3.1.2 Integrated and Sustainable Solid Waste Management

Sustainable solid waste management complements the **Green Economy** concept, especially when one considers the pivotal role of the solid waste sector in creating a low-carbon, circular economy whereby the generation of waste and harmful substances is minimised, the materials being reutilised, recycled or recovered are maximised and disposed waste is minimised, with all of these processes being managed to avoid damage to the environment and human health. The guiding principles to be taken into account in designing green SWM include sustainability, equity, efficiency, economic viability and diversity, producer responsibility, replicability, inclusivity and participation and job creation (Abaza, 2014).

Sustainable and integrated SWM (SISWM) or Green SWM is (IBRD, 2008):

1. essential part of ***successful local governance***
2. emphasises ***stakeholder participation and involvement***
3. emphasises ***occupational health and safety***
4. provides ***economic service delivery***
5. guarantees ***cost recovery***
6. is performed in an ***environmental friendly manner*** that minimises resource use and maximises resource recovery
7. contributes to ***job creation*** in the sector itself and encourages services and products in other sectors and industries
8. helps ***reduce the financial pressure on governments***.

The main aim became that of creating a "low-carbon economy" and linking resource depletion and solid waste generation. The green economy highlights issues such as "ecological services" and "natural capital", which were not given

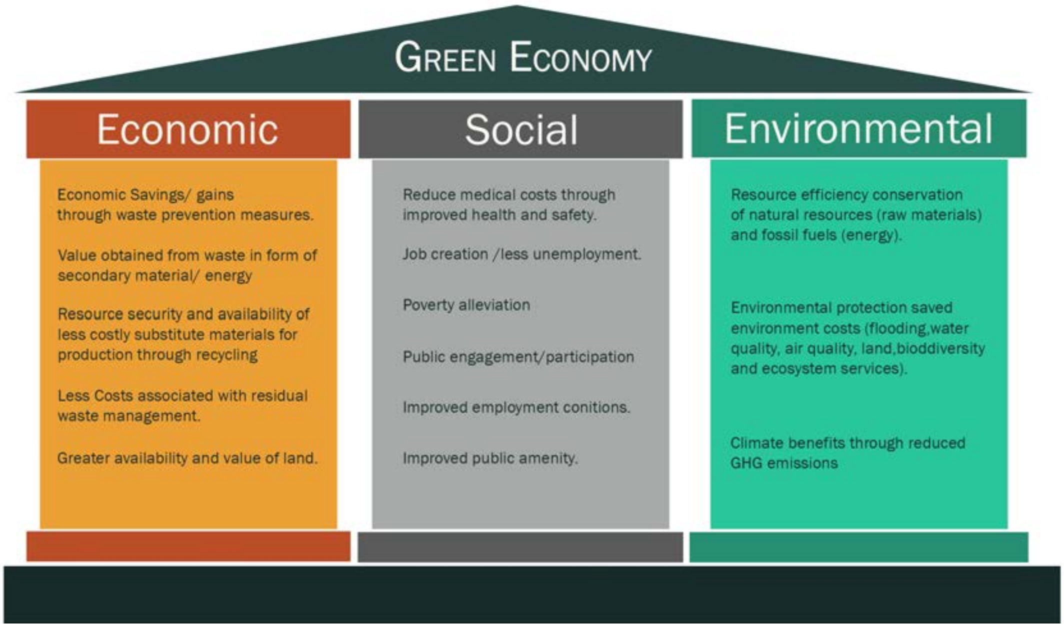


Figure 13: Green Economy Pillars and Associated Benefits

value in classical economies. It encourages investments that aim to "reduce carbon emissions, optimise resource use and prevent loss of biodiversity and ecosystem services". The focal sectors that may contribute to the green economy include "renewable energy, green buildings, clean transportation, water management, and waste management and land management".

3.1.3 Indicator

In order for the solid waste management sector to contribute to the green economy, the three pillars of sustainable development –social, environmental and economic sustainability – need to be met first (*Figure 13*).

Economic sustainability is achieved when the waste sector generates secondary material in a cost-effective manner, establishes new enterprises, provides more jobs, supplies affordable carbon neutral energy and minimises the amount of residual waste disposed. Funds and investments need to be directed to appropriate practices, infrastructure, equipment and services that are affordable to operate and maintain over their lifetime. Wherever possible, economic investments should encourage the financing of local technologies and enterprises.

Social sustainability is achieved when working conditions in the waste sector are safe and healthy for employees as well as for the public community. Employment in the green economy also needs to be concerned with other social factors such as the aspects of child labour, social protection and freedom of association.

Environmental sustainability of the waste sector to achieve green economy implies that resources should undergo life cycle analysis, starting with the production and manufacturing sectors to promote the production of non-hazardous goods and materials, resulting in the least amount of waste ultimately generated. Moreover, sustainable consumption should be promoted by addressing the consumer side through the implementation of waste prevention strategies.

Figure 14 shows the consequences of integrated and sustainable solid waste management.

Figure 14: Integrated and Sustainable Solid Waste Management Consequences (Modak, 2010; UNEP, 2009)

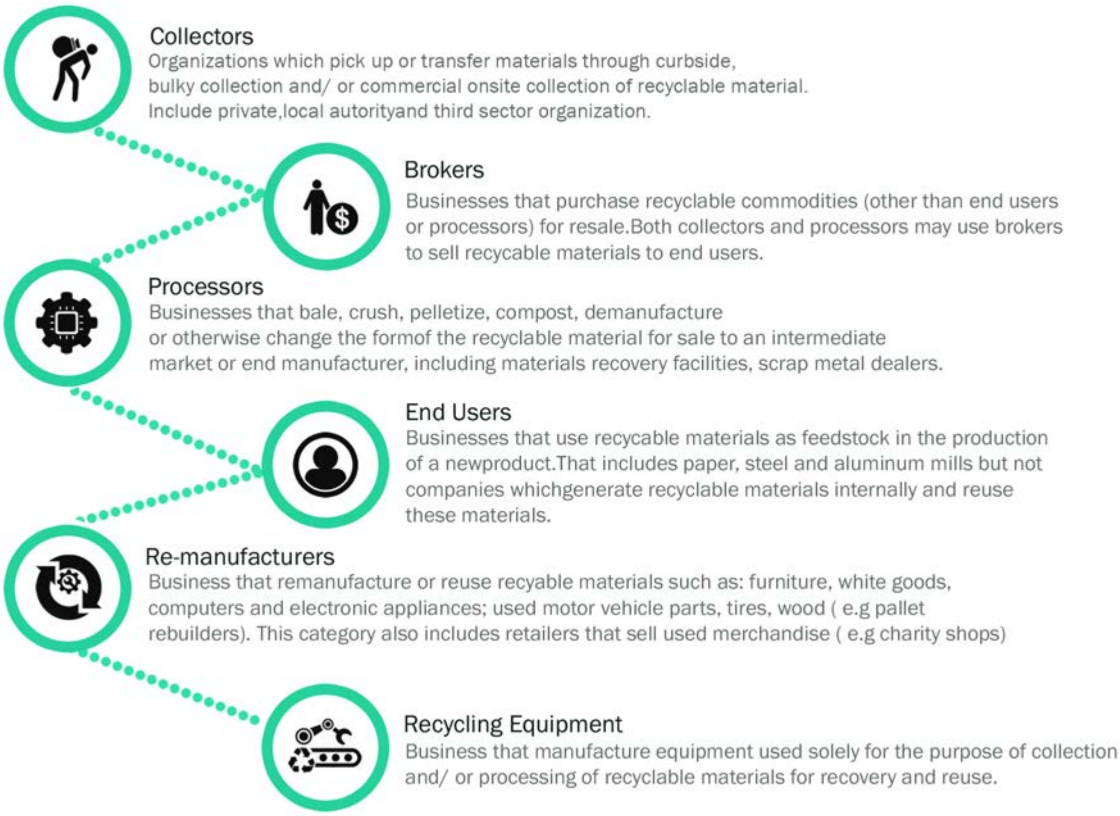


Figure 15: Related Job Activities to MSW Management (Friends of the Earth, 2010)

3.2. Benefits and Costs of Greening the Solid Waste Sector

3.2.1 Employment Generation

Activities related to MSW management vary widely and offer direct and indirect roles, as depicted in *Figure 15*. The new job roles generated by greening the waste sector will bring about a more skilled pool of labourers that is considered a value added as well, especially for developing countries. *Table 1* shows the estimated number of jobs created per 10,000 metric tonnes of waste for each operating strategy. It is obvious that, moving up in the waste hierarchy, more jobs can be created. In addition, new sectors have emerged, such as GIS/IT enabled services.

More job creation is maintained through scavenging in developing countries. The lack of adequate MSW collection and separation in developing countries gives good opportunities for scavengers (informal sector) to be engaged in such business. This creates a large need for informal scavengers and offers more income among the poor. This might help to eradicate extreme poverty and hunger as a goal of the SDGs.

Greening the waste sector and following an appropriate MSW management approach leads to employment generation where more employees will be required to successfully maintain a new management system. *Box 1* shows a case study in South Africa about job creation in the waste management sector.

Type of Operation	Jobs
Product Reuse	
Computer Reuse	296
Textile Reclamation	85
Miscellaneous Durables Reuse	62
Wooden Pallet Repair	28
Recycling-Based Manufacturers –Average	25
Paper Mills	18
Glass Product Manufacturers	26
Plastic Product Manufacturers	93
Conventional Materials Recovery Facilities	10
Composting	4
Landfill and Incineration	1

Table 1: Jobs per 10,000 metric tonnes/year of Waste (Source: ILSR, 2015; Eco Cycle, 2011; Modak, 2010)

Box 1

Cooperatives as a developmental vehicle to support job creation and SME development in the South African waste sector – challenges and successes

Photo: © Linda Godfrey

Linda Godfrey[1], Aubrey Muswema[1], Wilma Strydom[1], Thembelihle Mamafa[2] and Maxwell Mapako[2]*

[1]CSIR, Natural Resources and the Environment
[2]CSIR, Enterprise Creation for Development

The Government of South Africa intends to capitalise on the opportunities in the waste sector to address high unemployment (26.4% in 2015) and improve environmental sustainability. By 2016, it aims to have created 69,000 new jobs and 2,600 cooperatives in the waste management sector.

Cooperatives face many challenges, especially lack of infrastructure. Evidence suggests that cooperatives are currently weak and that 92% of them fail. This could be due to government's drive to register scores of cooperatives without providing sustainable business development support. Success also demands a greater integration with municipalities and the private sector.

Despite the challenges, there are several positive examples of cooperatives that have achieved excellent results in the waste sector, proving that cooperatives can create jobs to alleviate poverty. The 64 cooperatives that took part in this study created 1,905 jobs alone. Most cooperatives (97%) are working in the area of collection and sorting. Some identified areas of growth include: buy-back centres, recycling and manufacturing, expanding collection areas and collecting new types of recyclables like organic and electronic waste.

3.2.2 GHG Emission Reduction

Sources of GHG emissions from MSW management strategies are shown in *Table 2*. Greening the waste sector and mitigating GHG emissions are projected to earn yearly foreign exchange as certified emission reductions from the United Nations Framework Convention on Climate Change (UNFCCC) as a Clean Development Mechanism (CDM) project under the Kyoto Protocol.

Figure 16 presents the breakdown of global emissions from waste regionally. Global waste emissions per unit of GDP have been decreasing since 1970, with a sharp fall starting in 1990. This decrease can be attributed to the decrease of GHG emissions from waste in the EU, mainly from solid waste disposal on land, which decreased by 19.4 % in the decade 2000 – 2009 (Eurostat, 2013). In the EU, average emissions covered by the EU Emissions Trading System (ETS) between 2008 and 2012 were 11% below 2005 levels (EEA, 2014). The EU has implemented a powerful policy tool to reduce the amount of biodegradable municipal waste disposal to landfills through its Landfill Directive 10 1999/31/EC. Also, this decrease can be attributed to energy production from waste in the EU. In 2009, it was more than double that generated in 2000, while biogas experienced a 270 % increase in the same period (Fischedick et. al., 2014). The decrease in emissions per GDP can be also attributed to the changes in waste composition, increase in the amount of collected landfill gas and higher frequency of compositing.

A case study for using the waste as a potential source for biofuels and chemical production in one of the G8 countries, the UK, is presented in *Box 2*.

MSW Management Strategy	GHG Sources and Sinks		
	Raw Materials Acquisition and Manufacturing	Changes in Forest or Soil Carbon Storage	Waste Management
Source Reduction	Decrease in GHG emissions, relative to the baseline of manufacturing	Increase in forest carbon sequestration (for organic materials)	No emissions/sinks
Recycling	Decrease in GHG emissions due to lower energy requirements (compared to manufacture from virgin inputs) and avoided process non-energy GHGs	Increase in forest carbon sequestration (for organic materials)	Process and transportation emissions associated with recycling are counted in the manufacturing stage
Composting (food discards, yard trimmings)	NA	Increase in soil carbon storage	Compost machinery emissions and transportation emissions
Combustion (WtE)	NA	NA	Non-biogenic CO_2, N_2O emissions, avoided utility emissions, and transportation emissions
Landfilling	NA	NA	CH_4 emissions, long-term carbon storage, avoided utility emissions, and transportation emissions

Table 2: Sources of Net Emissions for Various MSW Management Strategies (U.S. EPA 2006a)

China's GHG emissions in the waste sector increased rapidly in the last decade as a result of the growing scale of waste generation by industries as well as domestic areas (Tas and Belon, 2014). A 79 % increase in landfill methane emissions was estimated between 1990 and 2000. This is due to changes in the amount and composition of generated MSW (Streets et al., 2001). Nevertheless, China is still one of the major countries in mitigating GHG emissions from waste management and disposal. It has earned a total of 15,654,538 Certified Emission Reductions (CERs) from waste management and disposal through 147 registered CDM projects out of a total of 3,876 CDM projects.

Figure 17 shows the total GHG certified emission reductions and shows that China is second only to Brazil among BRICS in gaining CERs for reducing GHG emissions from its waste management sector. This mechanism helps to improve the global partnership for development among G8, BRICS, and developing countries. Accordingly, it contributes to the targets of the SDGs to develop further an open, rule-based, predictable, non-discriminatory trading and financial system. Moreover, GHG emissions reductions in the waste sector help in ensuring environmental sustainability.

The decrease of GHG emissions in the waste sector in the EU and the United States from 1990 to 2009 was not enough to compensate for the increase of emissions in other regions, especially in developing countries, resulting in an overall increasing trend of total waste-related

Box 2

Waste not want not: Waste as a valuable biorefining resource for biofuels and chemicals production

Karen Wilson
Aston University, Birmingham, UK

Biomass derived from crop residues is a sustainable source of carbon that provides a low-cost alternative to fossil fuels used for transportation and organic chemicals. More than 900 million tonnes of waste (wood, agriculture and paper) produced in the EU annually. The EU recognises that GHG emissions could be reduced by 60% by using waste residues to supply 16% of transport fuels by 2030. (http://europeanclimate.org/wp-content/uploads/2014/02/WASTED-final.pdf)

Bio-refining of waste biomass would positively impact on renewable energy production by the co-production of high-value chemicals and products alongside fuels to improve the economic viability of the process, while reducing climate change, fossil fuel dependency and environmental pollution. Unlocking the potential of lignocellulosic agricultural residues for bio-refining requires new pre-treatment methods to fractionate biomass into lignin, cellulose and hemicellulose and the development of selective catalytic conversion technologies. Together these will reduce energy demands to make production more economically viable. The US Department of Energy has identified a range of sugar-derived platform chemicals, like 5-HMF, a widely known intermediate for the production of value-added chemicals and high performance liquid fuels.

This study demonstrated that the aqueous phase catalytic conversion of waste derived sugars in the UK can be used to produce fructose, HMF and furfural in good yields, even when using condensate from steam-exploded rice straw. A significant achievement was that HMF became the principal product, which is noteworthy since this was obtained using a feedstock with impurities. Further work will be conducted in this field.

GHG emissions in that period. This reveals that MSW is a global issue that needs more focus internationally and nationally. On the other hand, the G8 countries have an important contribution in reducing GHG emissions in developing countries as investing parties. *Figure 17* also shows the amounts of certified emission reductions that have been achieved by some G8 countries either solely or in collaboration with other developed countries.

A great effort is exerted worldwide to properly manage MSW and mitigate GHG emissions from the waste sector. It is also clear that MSW can present low-cost GHG emission reductions, for example through the installation of landfill gas capture systems, which require a relatively low-capital outlay. The opportunity to reduce GHG impacts associated with MSW is obvious from the number of registered CDM projects in the waste sector compared to other sectors *(Figure 18).*

In addition to the CDM mechanism, the EU trading of emission allowances is an important market instrument in climate policy. When using the trading of emission allowances as a climate-policy instrument, a limit is set for the total amount of emissions allowed. The basic idea is that one emission allowance is needed for every tonne of GHG emissions produced (Braschel et. al., 2013 a).

This emissions limit can then be reached by countries trading emission allowances in a cost-effective and economically efficient manner. Solid waste management has a potential impact in the European Union Emissions Trading Scheme (EU ETS). Clearly, increased knowledge of the potential impact arising from waste sector inclusion in the EU ETS would enable decision-makers to become more proactive in managing waste streams more economically (Braschel et. al., 2013b). However, as per the EU report on GHG projection guidelines issued in 2012, the waste sector projected GHG emission 1990 to 2020 for EU27 is less than 200 Mt CO2-equivalent annually. Compared to other sectors, such as Energy Industries and Transport, the waste sector is one of the lowest sources of GHG emissions in the EU (Clima, 2012).

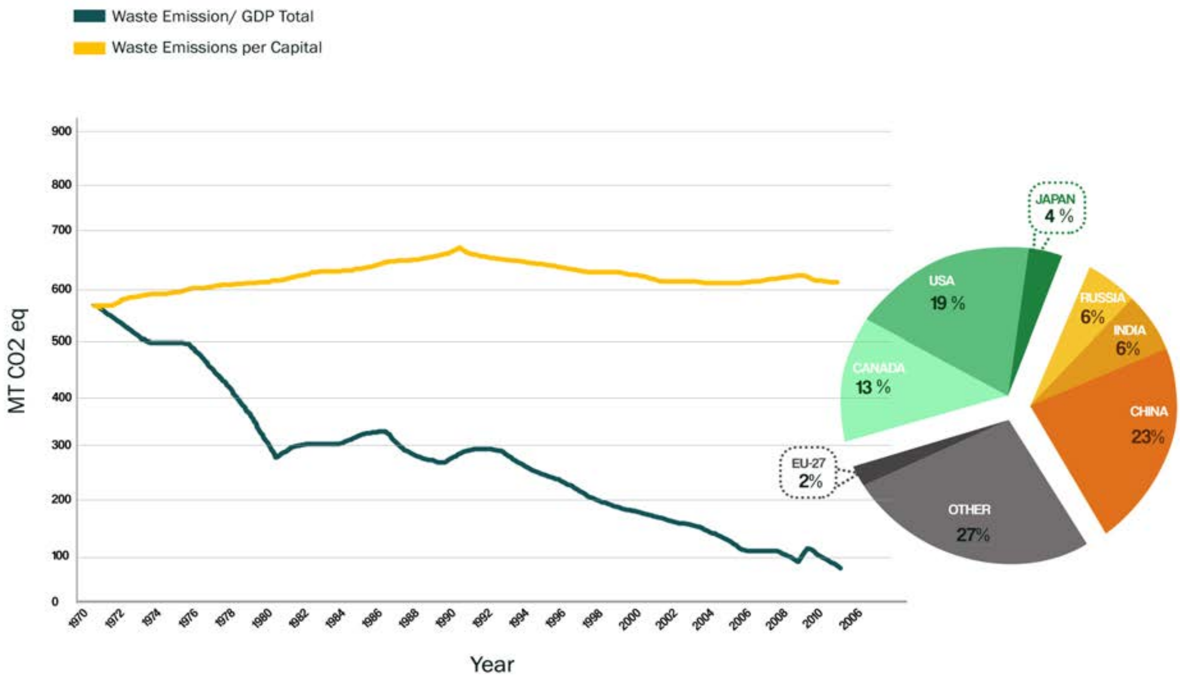


Figure 16: Global Waste Emissions Percentage and Waste Emissions/GDP and Waste Emissions per Capita (Fischedick et. al., 2014)

3.2.3 Energy Production

Significant and positive economic impacts of proper MSW management include providing a new source for energy generation.

Figure 19 shows the energy value of each component of MSW both as received and after drying. Drying the waste will reduce the moisture content and hence increases its calorific value. By correlating the energy value of each MSW component with the MSW composition in the three different regions (G8, BRICS and developing countries), for every 10,000 tonnes of waste, more energy can be generated from solid waste in developing countries. Due to the relatively high organic content of waste in developing countries, there is a bigger opportunity to generate renewable energy on a per tonne basis.

Figure 20 shows the potential energy that could be generated from different MSW components in different regions of the world. It should also be mentioned that the degradable organic content (DOC) and carbon content have an impact on the amount of potential energy. *Figure 21* shows the matter content for each MSW component.

From an energy perspective, estimates based on international experience suggest that each tonne of MSW can generate 150-650 kWh, depending on waste composition and the technology used for conversion. WtE systems form an essential component of an overall waste management system thanks to their ability to divert waste from the finite capacity of landfill. Energy produced by any WtE solution is simply a by-product of the waste management process. The ability to produce meaningful amounts of energy from WtE systems is limited, and there are cheaper and more scalable generating methods. Hence, any decision to proceed with a WtE solution should be based on its ability to manage waste and divert from landfill rather than the ability to generate energy.

In general, developing countries generate MSW with an energy potential towards lower end of the range as a result of less ‘valuable’ and more efficient consumption. Additionally, the informal sector, through scavenging and sorting, further reduces the energy potential of the waste.

A basic analysis of potential energy value in MSW clearly demonstrates that energy generation potential from MSW is large enough to be an attractive opportunity, but not large enough to change the energy landscape. Moreover, the cost of energy generation from MSW from different technologies is not likely to be competitive with other potential energy sources. It is

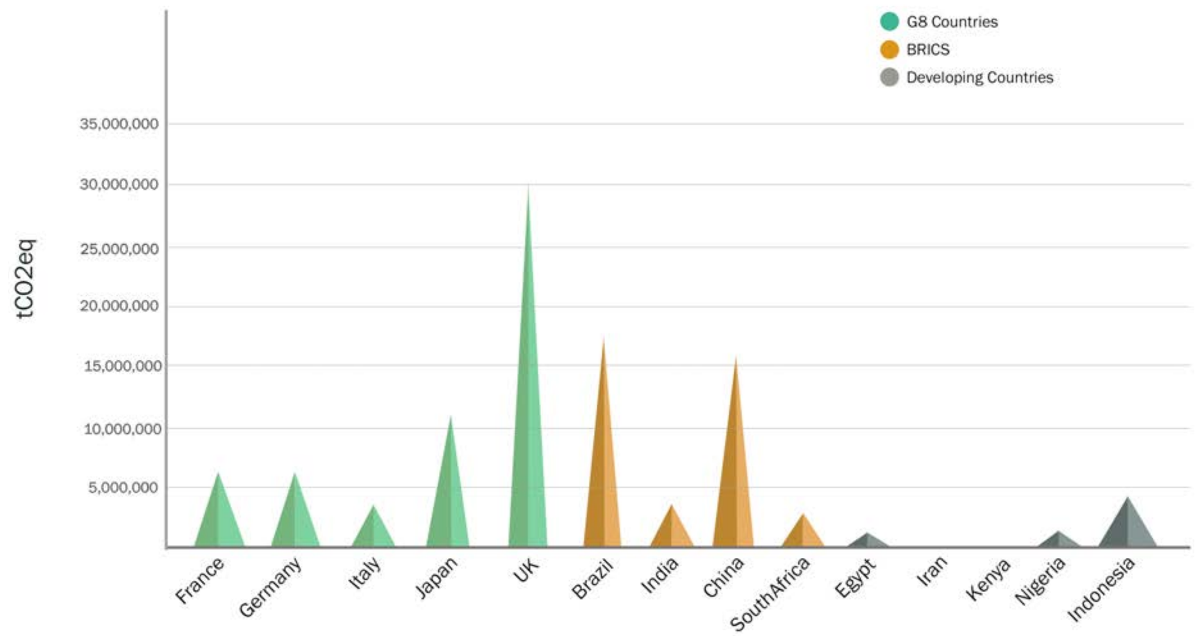


Figure 17: GHG Certified Emission Reduction for Waste Management and Disposal in Some BRICS and Developing Countries in addition to the Contribution of the G8 Countries* in Reducing GHG in the Waste Sector in Cooperation with Other Countries (UNFCCC, 2015)

critical to view WtE technologies from the MSW management angle, rather than from a pure energy generation focus. WtE technologies can allow the extraction of more value from MSW while disposing of it safely and sustainably, reducing the overall cost, both financial and environmental, thus addressing the MSW challenge (Chemonics, 2012). *Box 3* discusses the approach of the New South Wales Government in Australia, in seeking to encourage the sustainable integration of WtE into a waste management system where other resource recovery systems are already well developed.

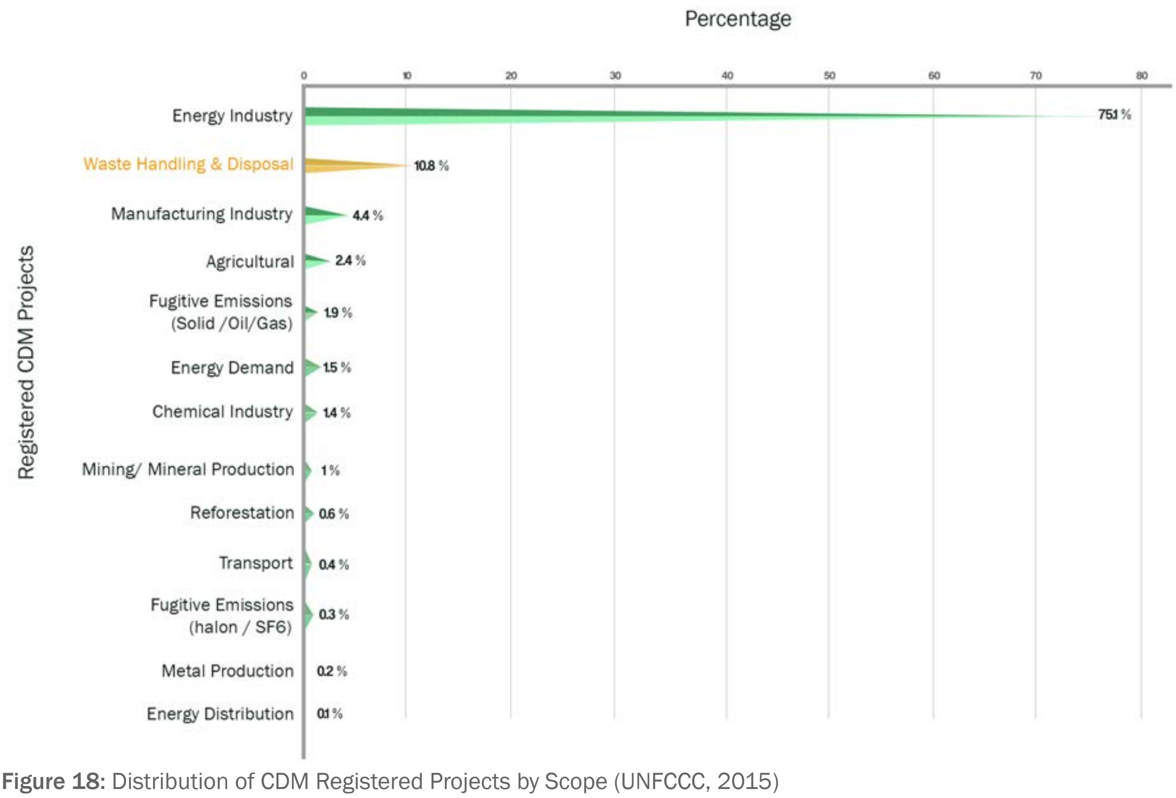


Figure 18: Distribution of CDM Registered Projects by Scope (UNFCCC, 2015)

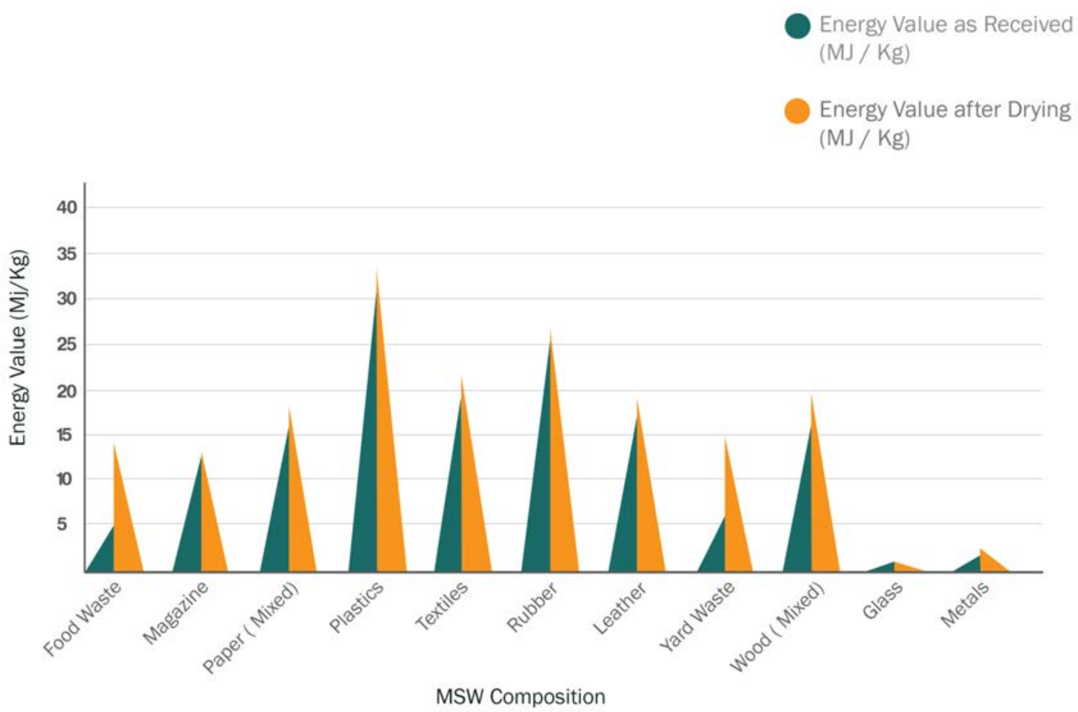


Figure 19: MSW Composition and Energy Value (Mihelcic and Zimmerman, 2010)

3.2.4 Health Impact

Poor waste collection and disposal results in environmental pollution and hazards to public health. Open dumping and burning deteriorates air quality. Health risks rise from the air pollution, but also from poor sanitation and uncontrolled leachate that contaminates surface and groundwater. Furthermore, unmanaged waste frequently blocks drainage systems and worsens flooding. In addition, waste in dumpsites and landfills contribute to greenhouse gas emissions (World Bank, 2014). In high-income countries (G8 countries), the main concern with infectious healthcare wastes is the transmission of HIV, which causes AIDS or hepatitis A and B through injuries inflicted by sharp edges. The USA reported a number of workers who were infected with HIV by contaminated puncture wounds as a result of solid waste segregation. However, the risk of hepatitis B virus infection from a comparable injury was estimated to be at least ten times higher than that of HIV (WHO, 2015; Beltrami et. al., 2000).

On the other hand, in the developing countries, waste-pickers earn a living through sorting and recycling of secondary materials. They have high occupational health risks, including risk from contact with human faecal matter, paper that may have become saturated with toxic materials, bottles with chemical residues, metal containers with residue pesticides and solvents, needles and bandages (containing pathogenic organisms) from hospitals, and batteries containing heavy metals of waste, all of which contribute to occupational health problems. Although the health risk faces most of the scavengers in developing countries, people are still joining this sector because it maintains higher income than other informal jobs (Sandra, 2006).

It is worth mentioning as well that waste management always relates to the total expenditures for health care. Based on WHO estimates, the spendable budget for waste management is estimated to be 5% of the health care budget per capita annually. Accordingly, waste management should be incorporated and be part of community health policy (Hoornweg and Bhada-Tata, 2012). People involved people in solid waste management processing and disposal facilities are exposed to environmental health and accident risks that relate to the emissions from solid wastes, the pollution control measures used to manage these emissions, and the overall safety of the facility. These risks are being managed in developed countries, but this is still

Exploring the Emerging Industry Response to 'Resource Recovery Criteria' mechanisms within the NSW EfW Policy

Photo © Garth Lamb

Garth Lamb
Re.Group, Sydney,Australia

The New South Wales Government's inclusion of 'Resource Recovery Criteria' is a novel regulatory approach to encouraging energy from waste (EfW) development without undermining recycling programs; it is designed to ensure energy is only recovered from materials with no higher-order recycling potential. The proportion of waste that can be used for EfW is restricted, based on the degree of source-separated recycling systems in place.

All Sydney households have at least a 2-bin collection system, one for MSW and one for mixed recyclables. Most households (70%) also have a third bin for garden organics, but only 10% of households have a food organics collection. Under the new (2014) EfW Policy, councils with a 2-bin system can send only 25% of their waste to EfW; councils with a 3-bin system can send 40%, and only those also offering food organics collection are allowed to send all of their residual waste to EfW.

The Global Renewables Eastern Creek (GREC) facility is the largest mechanical biological treatment facility in Sydney; it processes 220,000 tpa MSW and diverts over 65% of it from the landfill. Compost is the primary output; GREC sells over 70,000 tonnes of compost to the agricultural sector each year. GREC is implementing a new processing circuit to produce Refuse Derived Fuel (RDF) from the current residuals, increasing the facility diversion rate to more than 90%. Since 3-bin councils provide 75% of the waste and the remainder comes from 2-bin councils, the facility is limited to directing 35% of feedstock to energy recovery, equivalent to 70-80,000 tpa RDF.

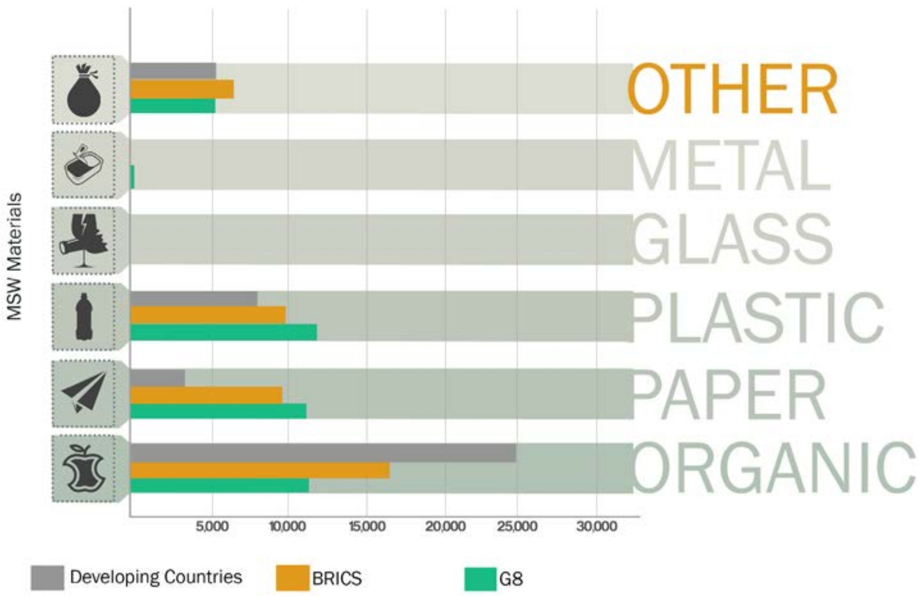


Figure 20: Potential Energy Generation from MSW Material in Different Regions (Mihelcic and Zimmerman, 2010; Bogner et.al., 2007; IPCC 2006)

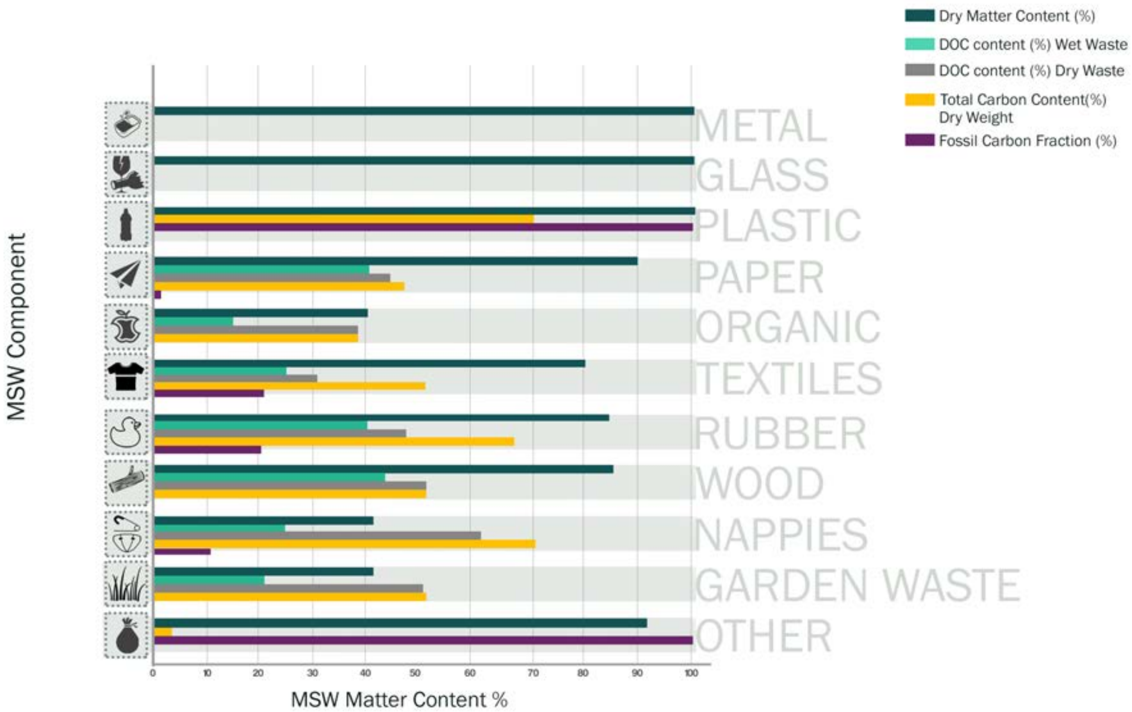


Figure 21: Municipal Solid Waste Matter Content (%) (IPCC, 2006)

being done improperly in most of the developing countries. As a matter of fact, pollution abatement costs money. External financial assistance is needed to support low-income communities in their environmental and health efforts to move towards green economy. Solid waste management involves risk at every step in the process, starting from the point where residents handle wastes at home to the point of final disposal. The health impacts of poor solid waste management can result in (Sandra, 2006):

1. Birth Defects and Infant Mortality
2. Air Pollution Disease Links
3. Direct Contact Disease Links
4. Water Contamination Disease Links
5. Animal Feeding Disease Links

Figure 22 also shows the health effects of waste management facilities. As a consequence, greening the waste sector by moving upward in the solid waste hierarchy and reducing the waste generations by promoting the 3 Rs strategy will mitigate the public health issues. However, we might need immediate actions in parallel by applying the following measures to alleviate these health impacts and contribute to ensuring healthy and long lives for all as a main target of the SDGs:

- Enforce solid waste scavengers to wear gloves and appropriate shoes and protective clothes, especially in developing countries.
- Upgrade open dumps to controlled sanitary landfills where leachate can be treated and landfill gas can be generated.
- Provide trainings and general work arrangement for workers in the solid waste sector and highlight the importance of washing before eating, smoking or drinking.
- Vaccinate solid waste scavengers for severe health problems, such as hepatitis A and B, tetanus and typhoid.
- Prohibit burning solid waste in open yards and dump sites
- Enforce solid waste burying and covering to avoid run off water (leachate) from reaching surface water bodies or groundwater.
- Prohibit children from waste picking and domestic animals from being fed with food waste.
- Conduct periodic monitoring and gate inspection and control at all disposal facilities.

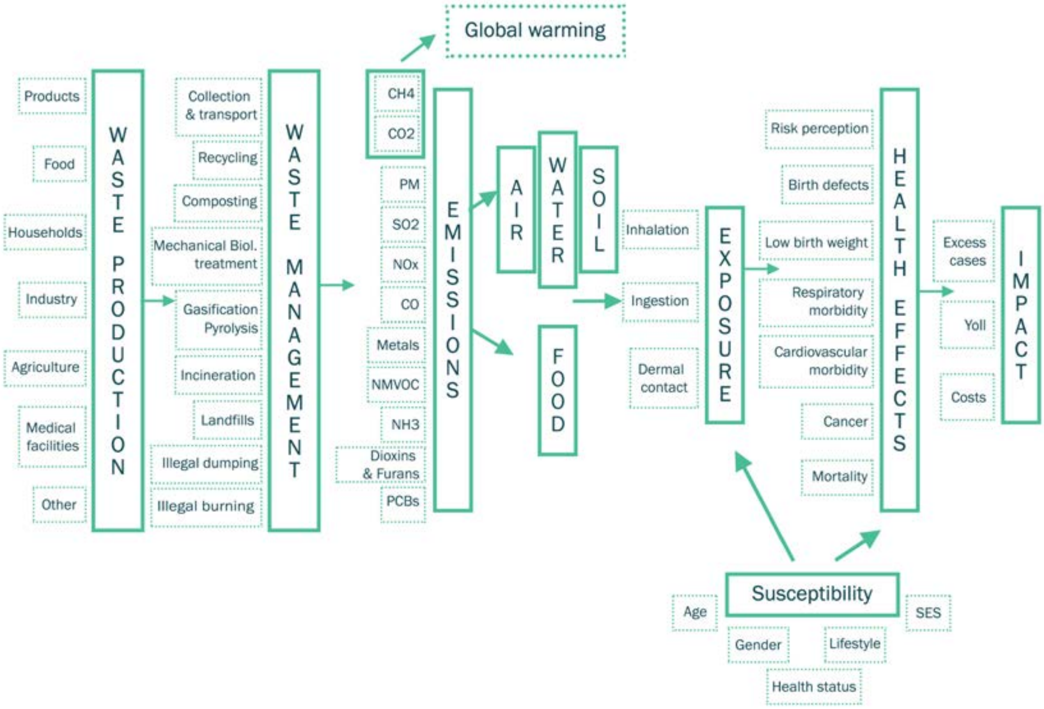


Figure 22: The Full Chain Approach from Waste Production to Health Effects (Forastiere et.al., 2011)

3.2.5 Cost of Greening the Waste Sector

Many alternatives for an MSW management approach or strategy are available for mitigating environmental negative impacts of MSW and greening the waste sector. An indicative cost for each MSW management systems approach should be identified in correlation with its potential for greening the waste sector.

Landfill disposal is the most inexpensive waste management option in the EU with an average of 52 USD/t, but it is the largest source of GHG emissions. From an economic perspective, landfilling is not preferred because it is the lowest job-creation option. The costs for composting can range from 18–156 USD/t waste and are typically 32 USD/t waste for open-windrow operations and 46 USD/t for in-vessel processes (Bogner et. al., 2007). The actual costs of the abatement options vary widely across regions as well as the selected management option. The actual cost of MSW management approach differs between types of waste, climatic regions, the age of a landfill and the different design approach for each technology. Many studies relate the cost of the abatement MSW strategies with the amount of mitigated GHG emissions. The U.S. EPA has produced two studies (Global Mitigation of Non-CO2 GHG Emissions and Gobal Mitigation of Non-CO2 GHG 2010-2030) with cost estimates of abatement in the solid waste sector which found a large range of options to reduce landfill gases, such as incineration, anaerobic digestion and composting, of up to 600 USD/tCO2eq if the technology is only implemented for the sake of GHG emission reduction (Fischedick et. al., 2014). However, the studies highlight that there are significant low-cost opportunities for CH4 reductions in the landfill sector involving flaring and CH4 utilisation. Six management approaches or strategies for solid waste are assessed and shown in *Figure 23*. The cost and potential of each different approach has been identified from IPCC 2006 guidelines and U.S. EPA 2006 and 2013 (Fischedick et. al., 2014). The minimum and maximum equivalent CO2 emission intensity (EI) of each MSW management practice is given in *Figure 23.* Landfilling has the highest CO2eq EI range compared to other MSW practices. The average cost of conserved carbon from municipal solid waste disposal is derived by comparing emission range from landfilling as a benchmark with the emission range for a chosen technology. The cost of each MSW strategy is directly taken from Technology – Specific Cost and Performance Parameters (Fischedick et. al., 2014). *Figure 23* provides an indicative price for different MSW practices compared with landfilling as a business as usual scenario.

Besides providing mitigation of GHG emissions, adopting a proper MSW systems approach offers significant indirect economic benefits, such as creating green jobs and improving the environment and public health. In developing countries, improved waste management using low- or medium technology strategies is recommended to provide significant GHG mitigation and public health benefits at lower cost, such as controlled composting of organic waste (IPCC, 2007). The major barrier for developing countries to implement advanced MSW management practices and technologies is the lack of capital. The technologies adopted by the developing countries must ensure sustainable long-term solutions. Therefore, the selection of viable sustainable MSW systems approach is very important. *Box 4* shows a good example of an economic viability study of biodiesel production from waste cooking oil in the United Arab Emirates. This case study reveals the economic benefits for UAE from using biodiesel oil and the amount of carbon dioxide emission reductions.

3.3. Opportunities for Greening the Waste

Opportunities for greening the waste sector can be created and managed before reaching the end user consumers "Pre – Consumer Waste" and after collecting generated wastes from end user consumers "Post-Consumer Waste" (*Figure 24*). This will help in ensuring sustainable consumption and production patterns as one of the SDGs. *Box 5* discusses different opportunities that can be adopted in Kenya, one of the developing countries, for greening the waste sector.

3.3.1 Waste Reduction

Waste reduction at the pre-consumer stage can be achieved by optimising the use of raw materials, e.g. maximum utilisation of material with minimal waste by properly arranging the raw patterns of fabrics, metals, etc. The approach of waste reduction is always attractive, especially on small islands or in countries with limited land availability, such as Europe. *Box 6* depicts a

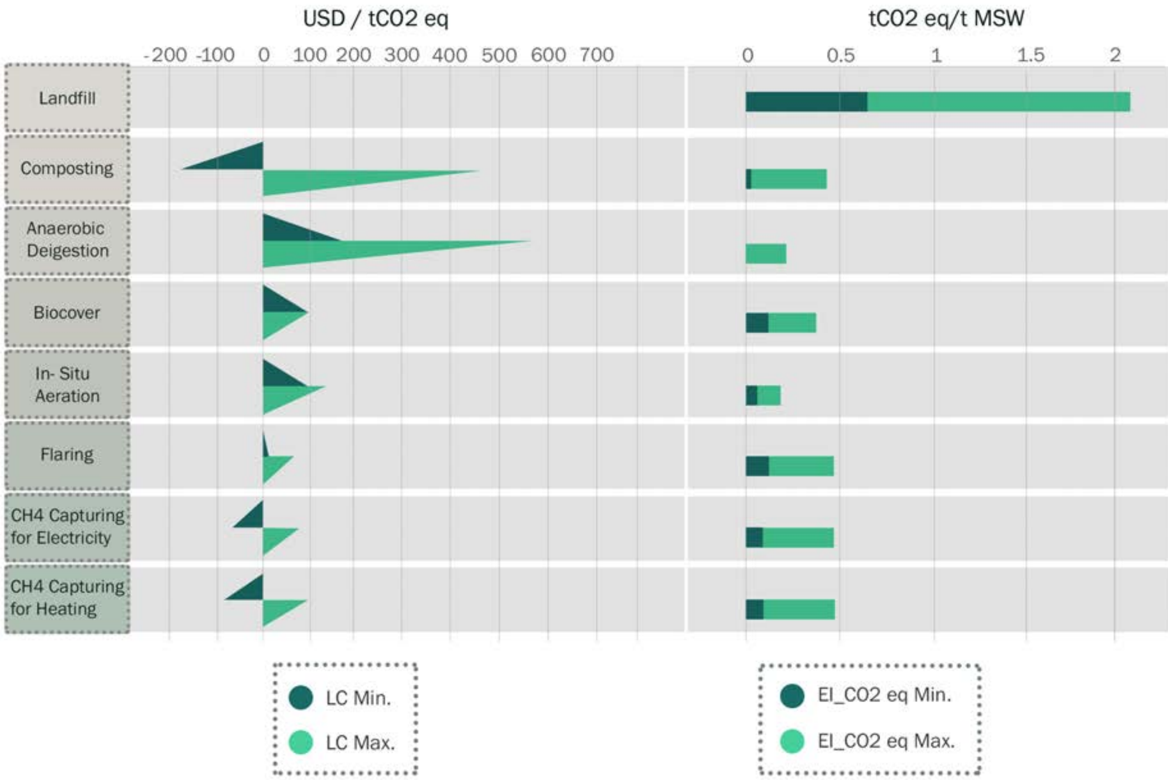
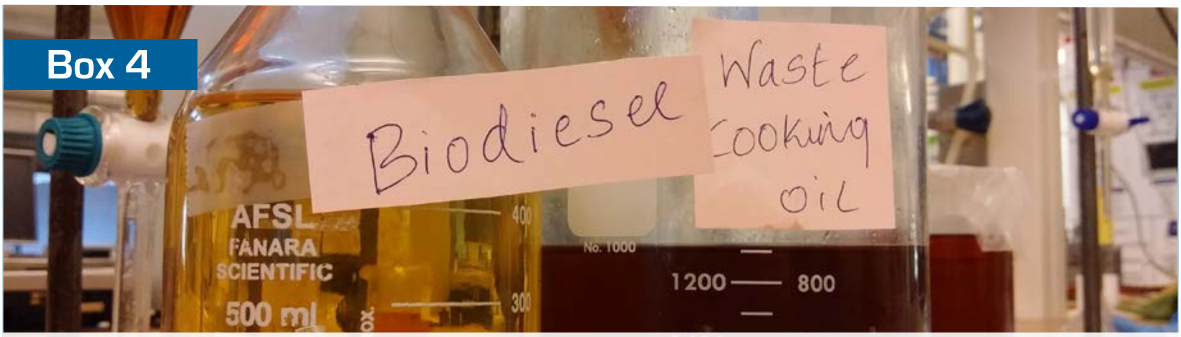


Figure 23: Indicative CO2eq Emission Intensities and Corresponding Average Cost of Municipal Solid Waste Disposal Practices/Technologies (Fischedick et. al., 2014)

Box 4



Economic Feasibility of Biodiesel Production From Waste Cooking Oil in the UAE

Photo © Isam Janaireh

Mohammad N. Hussain, Tala Al Samad and Isam Janajreh
Masdar Institute, Abu Dhabi, UAE

This study aimed to determine the economic feasibility of producing biodiesel from waste cooking oil in the UAE. A survey was conducted to determine the type and amount of oil used, the drainage method and the quality of waste cooking oil in both the residential and commercial sectors. Using seven economic scenarios, the conventional (mechanical) method was compared to the sonicated production method, and results were assessed by the selling price, net present value and internal rate of return. In all scenarios, the break-even point was three years.

Although sonication production costs were higher, the larger output in a shorter time allowed for lower selling prices and thus produced larger profits. Also, large-scale production enables a reduction in selling prices and subsidies. Thus, large-scale production with sonication and no oil incentive is the most economically viable model.

Through a combination of project profits, CO2 emissions reductions, and solving drainage issues from improper disposal, the government would gain threefold. Biodiesel cut emissions by 23% per car, which translates to a 93,600-tonne reduction of net CO2 emissions per year achieved by utilising waste cooking oil for biodiesel.

Box 5

Solid Waste Management and Green Economy in Developing Countries

John N. Wabomba
University of Nairobi, Nairobi, Kenya

With only 40% of waste collected and properly dumped at designated sites, Kenya's solid waste management (SWM) sector requires immediate attention. In Nairobi, 2,000 tonnes of solid waste is produced daily, with only one official landfill to meet needs. SWM is addressed in laws and regulations, but waste reduction and recycling policies are lacking. Separation of waste at the source is expected to improve the value of the recyclables and result in higher profits for waste recovery and trading, encouraging more market activity. Food and organic wastes represent 61.4% of the generated MSW, which could be separated for composting or bio-refining. Currently, only 5% of the organic waste is composted. Recycling of non-organic solid waste is currently at 3-7%; there is an opportunity to produce and sell high volume products with commingled plastic. Waste to energy is another valuable option. Recovered and recycled glass, metal, paper and plastics have an export potential.

Kenya's war on Electronic wastes (E-wastes), such as computers, mobile phones and other electronics, has however, received a boost with the launch of a new recycling facility in Athi-River by the East African Compliant Recycling (EACR). The plant is a public private partnership (PPP) between Hewlett-Packard (HP), the German development bank (DEG) and EACR. The facility aims at separating and dismantling E-waste(s) in an environmentally responsible fashion, establishing a registered collection system for E-wastes in Kenya and creating job opportunities around proper E-waste management.

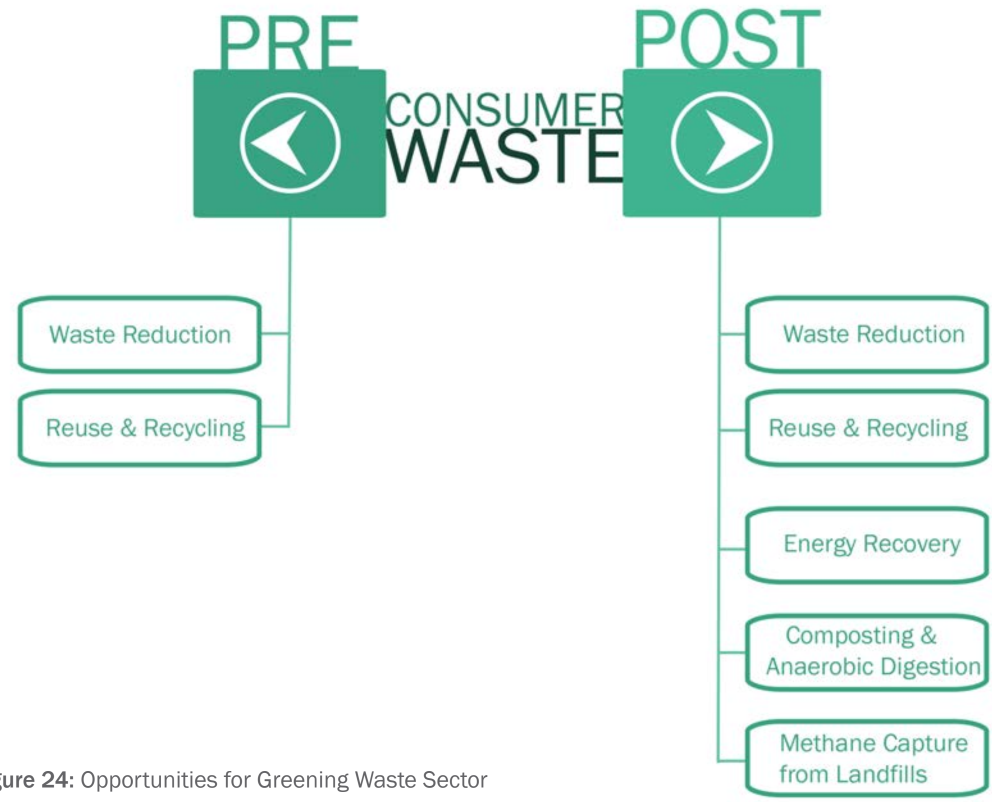


Figure 24: Opportunities for Greening Waste Sector

case study in Hawaii for proper industrial hazardous waste management.

On the other hand, the amount of the post-consumer waste is affected by the communities' lifestyle, consumer behaviour and applicable regulations. For example, Japan and the EU have the equivalent of about 60% of the US waste generation rates per capita (Fischedick et. al., 2014). A global visionary goal of 'zero waste' has been formulated as a major contribution towards greening the waste. Some industries are starting to target the approach of "Zero Waste" as an economically viable solution to save energy and raw materials. The European Commission adopted the end of waste concept in 2005 (EC, 2008). *Box 7* presents how cement factories in the Czech Republic are moving towards the concept of "Zero Waste".

The "Zero Waste" initiative assists countries in designing waste reduction strategies, technologies, and practices, keeping in mind other resource availability like land. Moreover, the non-technological strategies, such as reducing waste generation and enhancing the use of materials that are easy to recycle or reuse, help in reducing waste by decoupling MSW generation from economic activity levels (Mazzanti and Zoboli, 2008). Consequently, post-consumer waste is very much linked with the pre-consumer behavioral strategy. The concept of extended producer's responsibility (EPR) includes a recognition of the importance of various stakeholders in the consumption chain (from producers, to consumers and municipalities) to share the costs of appropriately managing waste.

Developed cities are aiming to transform their current waste management practice into more efficient and sustainable systems, and some have established "zero waste" goals. The concept of ''zero waste" meant designing and managing products and processes systematically to avoid and eliminate the waste and materials, and to conserve and recover all resources from waste streams through recycling 100% of their waste or recover all possible resources from waste streams and produce no harmful waste to the environment. As this task was challenging, these systems were analysed based on five waste management contexts: social, economic, political, technological and environmental. It was concluded that the tools, methods, or strategies developed for recycling or managing waste in zero waste cities should be affordable in the socio-economic context, regulatory or manageable in the socio-political context, applicable in the policy and

Box 6

Sustainable Waste Management on an Industrial Island

Photo © Matthew Eckelmann

Matthew Eckelman
Northeastern University, Boston, USA

Oahu, Hawaii is a remote but populous island with one of the highest per capita municipal solid waste generation rates in the US. Incentivised by high energy costs, several companies have created an industrial symbiosis, an innovative waste reuse method that involves mutually beneficial exchanges of water, energy and by-products. Nearly 300,000 tonnes of industrial by-products and 10 million m^3 of water have been shared annually as a result of their coordination. In doing so, they have reduced energy use, emissions and waste, preserved local resources and avoided the import of costly virgin materials. Life cycle assessment (LCA) of the symbiosis revealed GHG emissions reductions of 200,000 tonnes CO_2e, or fully 25% of the state's goal for industry, all through voluntary, private actions taken in the interest of reducing waste generation. This combined with other existing and potential commercial reuse and recycling activities (such as for building materials) identified could divert nearly half of Oahu's MSW, greatly reducing pressure on local treatment and disposal infrastructure.

Box 7

The concept of end of waste and recycling of hazardous materials: Magnesium cement and calcium sulfoaluminate clinkers produced from product of inertisation of cement-asbestos

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Centrum Excelence Telč, Telč, Czech Republic
Institute of Theoretical and Applied Mechanics, Praha, Czech Republic

In 2005, the European Commission adopted the end of waste concept, which encouraged treating wastes as a resource. We report two examples in which a class of hazardous wastes, asbestos-containing materials (ACMs) are recycled into secondary raw materials. One alternative solution to safe disposal of ACMs is thermal inertisation. A large-scale plant was devised to treat ACMs on an industrial scale, but it is essential to use the inert product as a secondary raw material. This report demonstrates that the inert ACMs can be used to prepare magnesium phosphate cement (MPC) and calcium sulfoaluminate (CSA) cement clinker. It was shown that up to 48% ACM could be recycled in an MPC mix, thus transforming a hazardous waste into a valuable secondary raw material, namely cement. Inert ACM can also be used to produce CSA clinkers; up to 29 wt% of the secondary raw material can be added to the mix. The use of inert asbestos is a feasible method of recycling hazardous waste, which saves energy and preserves natural resources in cement manufacturing.

Box 8

Sustainable End of Life Management for Complex Consumer Products

Photo © Edwin Tam

Edwin Tam and Susan Sawyer-Beaulieu
University of Windsor, Windsor, Canada

In 2009, Canada proposed an extended producer responsibility (EPR) initiative to capture products from the post-consumer phase. EPR success depends upon unit operations and management activities that impact materials recovery. However, the majority of EPR programs target simple products, such as packaging and materials. This research examines end-of-life management (EoL) for durable, complex products, like automobiles. EoL includes reduction and reuse, and can generate economic value by capturing waste materials that can be sent back for manufacturing.

However, durable goods pose significant challenges to waste management systems because of their complexity and composition: they are often made from multiple, distinct materials and then bonded together. Such items can be difficult and costly to separate. Plastics, one of modern society's most versatile and common materials, pose additional challenges. For example, end-of-life vehicles (ELVs) are one of the greatest contributors of plastic waste. These usually end up in shredder residue (SR) after waste processing. SR is a mix of materials, with a roughly 41% plastic share, is usually landfilled and is sometimes even considered as hazardous waste.

Research was undertaken to determine if recycling practices could be augmented to enhance recovery. Various processes were used to break up plastic auto components. In particular, preconditioning through moderate cryogenic freezing has the potential to improve the separation of different plastics. Design-for-disassembly (DfD) initiatives could also improve recovery.

Next, a comprehensive life cycle assessment was performed to characterise the dismantling industry. Older models are typically only recovered for scrap value. However, recovering parts from recent models ELVs can result in up to 37% by weight of high-value parts for resale and reuse. Remanufacturable and reusable parts constitute about 6% of what is recovered from ELVs, but their potential is likely undervalued. Overall, automotive recycling is a $32B industry in the US, employing over 140,000 people. Increasing the focus on parts recovery for reuse and remanufacturing from complex, durable goods –along with improved separation and recovery approaches –offers significant future potential to generate additional economic value while addressing critical waste related concerns.

technological context, effective or efficient in the context of economy and technology, and finally all these aspects should be directly related to environmental sustainability (Zaman and Lehmann, 2011).

Policies and regulation that encourage more sustainable production and consumption are considered one of the main pillars towards greening the waste sector. Accordingly, in 2009, Canada proposed an EPR strategy for a sustainable end of life management for complex consumer products, as discussed in *Box 8.*

3.3.2 Reuse and Recycling

In the pre-consumer stage, material substitution through waste generated from an industrial process or manufacturing chain can lead to a reduced demand of raw materials, total energy requirements and thus minimises GHG emissions. Successful recycling systems require careful consideration of costs involved and of the markets for recycled goods. Expansion in recycling requires the development of new markets. Otherwise, the excess of supply over demand will lead to decreases in the value of the recovered materials, to the point that more resources are used to recover the materials than are saved by the recovery (ASTM, 2013).

While in the post-consumer stage, if waste prevention cannot be achieved as a first approach towards minimising MSW generation and greening the waste sector, reuse and recycling should be investigated as a second priority to avoid the materials being disposed as 'waste'. It has been reported that reusing or recycling the waste can be achieved with high economic value to protect the environment, avoid natural resources depletion and create green jobs (El Haggar, 2010).

As the quantities of waste are globally rising, MSW can be seen as a material reservoir that can be mined and utilised beneficially. Accordingly, proper depositing of substances (i.e. metals, paper, and plastic) is important in order to make their recovery technically and economically viable in the future, either for reuse/recycle or energy recovery. This should be managed through a high degree of agreements and protocols (Sims et. al., 2007). Good examples of Reuse/Recycling are: the UNEP/UNIDO Cleaner Production Approach, China's Circular Economy Approach, Japan's Sound Material Recycling Society and 3Rs approach and the EU's Waste Prevention and Recycling Strategy. *Box 9* and *Box 10* show two different case studies for reusing and recycling the waste.

3.3.3 Energy Recovery from Waste

Generating energy from waste as a by-product can be an economically viable and valuable option in selecting MSW management system approaches that make a significant contribution to greening the waste sector. The organic components of MSW consist of biogenic substances with carbon atoms. Carbon from using biogenic fuels has implications for estimating the efficiency and environmental benefits of the waste to energy process. Energy can be recovered from waste by thermal treatment technologies (including combustion, gasification and pyrolysis), mechanical-biological treatment (MBT), anaerobic digestion, or torrefaction.

Currently, around 200 Mt per year is estimated as the world's WtE capacity. About 90% of this amount is based on combustion of as received solid wastes on a moving grate (Themelis and Ulloa, 2007). Most of the WtE technologies

Box 9

Chitin and Chitosan as Natural Flocculants for Clarification and Inhouse Enzymes for Haze Removal in a Microbrewery Sustainable Bioeconomy Case

Satinder K. Brar
Institut national de la recherche scientifique, Centre, Quebec, Canada

Beer is stored at an ambient temperature after production, leading to haze formation—a persistent problem in the brewery industry. Beer production in Canada usually involves a flocculation stage to remove turbidity and avoid haze formation utilizing either bentonite or Stabifix, both of which require high doses and neither of which are environmentally friendly. Chitosan and chitin are two environmentally friendly alternatives; they are inexpensive, biodegradable and non-toxic to mammals. Chitosan proved far better than conventional flocculants as it provided better turbidity reduction with a 160 times lower dose. Chitin also performed well compared to traditional bentonite and Stabifix coagulants since it provided higher turbidity reduction at a lower dosage. The use of chitin and chitosan as bioflocculants reduces flocculation time from 10 days to 2 days, and can increase production by 5 times whilst decreasing flocculent costs nearly tenfold, thus increasing profits.

Box 10

Difficulties Associated with the Justification and Optimisation Principles regarding the use of NORM Phosphates Residues for Building Material Construction in Brazil

Paulo F. L. Heilbron Filho and Jesus S. P. Guerrero
CNEN/Brazilian Nuclear Energy Commission, Rio de Janeiro, Brazil

This study discusses the use of Naturally Occurring Radioactive Material (NORM) residues, like phosphogypsum, in housing construction in brick and plasterboard production. In Brazil, the practice is difficult to approve due to radiological protection principles like justification, dose limitation and optimisation. A complete risk analysis was performed to determine the radiation risks for people living in housing containing phosphogypsum residues. In this model, phosphogypsum was mixed with non-radioactive gipsita and then integrated into a concrete building block. Due to uncertainties in cost and risks associated with mixing radioactive materials, it was shown that this practice is no longer justifiable in Brazil. However, in countries where there is already a high concentration of naturally-occurring radioactive materials in housing construction, the use of phosphogypsum in construction may be justified, depending on the dose constraint value.

Box 11

Unlocking the potential of municipal solid waste to meet energy demands for Kampala City, Uganda

Photo © Noble Banadda

Noble Banadda and F. Ayaa
Makerere University, Kampala, Uganda

The Ugandan Government set targets to produce at least 15 MW from municipal solid waste (MSW) by the end of 2012 and 30 MW by 2017. Approximately 1,500 tonnes of solid waste is generated in Kampala City daily, which is landfilled, burnt in the open, or dumped haphazardly. The MSW waste composition of Kampala City is primarily made up of food and yard waste (90.64%). This project aimed to determine the energy potential of municipal solid waste through pyrolysis and incineration. In this study, computational fluid dynamic modelling was used to evaluate and optimize incinerator performance. The design was optimised with several iterations. Incineration took 31 minutes compared to 25 minutes for typical incinerators. Incinerator capacity was also slightly lower than normal, 460 kg/hr compared to 567 kg/hr due to the high moisture content of the organic waste. MSW from Kampala was found to be suitable for incineration.

require high capital costs. Consequently, they are more prevalent in advanced economies (G8-Countries) with high GDP levels. China is considered a special case as one of the BRICS countries because it has implemented more than 100 WtE plants in the last decade (Dong, 2011). However, some developing countries are starting to encourage WtE. This should not be at the expense of local recycling economies. It is crucial that emerging and developing countries carefully consider the appropriateness of alternative waste treatment technologies, so that they don't get locked into technologies which may be more appropriate for developed countries. Given the high organic content in developing country waste streams, AD and biogas recovery should be a priority before incineration or pyrolysis. Uganda, for instance, has set the target of producing 30 MW from solid waste by 2017 (*Box 11*).

3.3.4 Methane Capture from Landfills

Capturing and utilising landfill gas significantly helps to reduce global warming since the methane global warming potential is 25 times that of carbon dioxide (IPCC, 2007). It has been estimated that about 50 million tons of methane is generated annually from global landfills. The top five emitting countries account for more than 20 % of the total potential in the sector, and they are: United States 2 %, China 6 %, Mexico 9 %, Malaysia 3 %, and Russia 2 %. The distribution of the remaining potential per region is: Africa 16 %, Central and South America 9 %, Middle East 9 %, Europe 19 %, Eurasia 2 %, Asia 15 % and Canada 4 % (U.S. EPA, 2013).

3.3.5 Composting and Anaerobic Digestion

Composting is a microbial process that takes place in the presence of air and moisture in waste piles and results in the degradation of biodegradable constituents to produce carbon dioxide and solids (compost). Compost can have an economic value as a soil conditioner and fertiliser. In China, for instance, the production of sludge from wastewater treatment facilities is on the increase, with an estimated amount of 36 million tonnes in 2015. Composting this amount of sludge to enable beneficial use of the product to improve soil health and agricultural productivity can significantly contribute to greening the waste sector and the national economy of China (*Box 12*).

Adopting a composting approach can alleviate several environmental issues and concerns and make composting an environmentally and economically viable choice. Composting reduces the mass of waste and pollution potential, destroys pathogens, and produces a tradable product (compost).

As presented in *Box 13* decentralised composting programs at household level have been successful in some regions. In Indonesia, for instance, the households are using the Japanese home compositing bins, Takakura, to compost their organic waste in a decentralised approach and avoid delivering waste to centralised landfills.

The ability to capture and utilize biogas produced from anaerobic digestion of food waste after separation might also encourage investors or decision-makers. Kenya has established a mega biogas project to generate 2.2 MW from biogas, as well as also producing green fertilisers (*Box 14*).

3.4. Upcycling in Green Economy

Upcycling, also known as creative reuse, is the process of transforming by-products, waste materials, useless and/or unwanted products into new materials or products of better quality or for better environmental value than the originals. The first recorded use of the term upcycling was by Reiner Pilz of Pilz GmbH in an article by Thornton Kay of Salvo in 1994 (Kay, 1999). The concept was later incorporated by William McDonough and Michael Braungart in their 2002 book Cradle to Cradle: Remaking the Way We Make Things (McDonough and Braungart, 2002). They state that the goal of upcycling is to prevent wasting potentially useful materials by making use of existing ones. This reduces the consumption of new raw materials when creating new products. Reducing the use of new raw materials can result in a reduction of energy usage, air pollution, water pollution and even greenhouse gas emissions. These benefits are also there for recycling or down-cycling, but the quantities involved may be different.

Upcycling is in contrast to down-cycling, which another potential outcome of the recycling process. Downcycling involves converting materials and products into new materials of lesser quality or value. Most recycling involves converting or extracting useful materials from a product and creating a different product or material (EPA, 2015).

Upcycling is a creative modification of discarded objects in such a way as to create a product of higher quality or value than the original toward upper end of the innovation scale. Upcycling eliminates the concept of "Waste" by exploring the way materials are classified as technical nutrients for recycling or as biological nutrients which can then be safely returned to earth. The goal of "upcycling" is to "design and manufacture in a way that loves all of the children, all of the species, all the time". Upcycling is possible now more than before, largely because of technological advancement. Upcycle is "How the world gets better instead of just less bad". If there is a meme about upcycle, it's that we can do better, that we can always do better. It is about constant improvement (McDonough and Braungart, 2014)

Upcycling is seen to have many benefits associated with it, in particular environmental benefits. Upcycling helps to minimize waste that goes to landfill sites which produce methane, a greenhouse gas. It also benefits the environment by reducing the consumer demand for manufactured goods. These factors make upcycling an attractive option in the face of Africa's environmental metrics, whether they are community centered or internationally imposed, such as the MDGs.

For example, during the recycling process of plastics other than those used to create bottles, many different types of plastics are mixed, resulting in a hybrid. This hybrid is used in the manufacturing of plastic lumber applications. This is depicted in *Figure 25* and *Figure 26*. In developing countries, where new raw materials are often expensive, upcycling is commonly practiced, largely due to impoverished conditions.

Upcycling has seen an increase in use thanks to its current marketability and the lowered cost of

Box 12

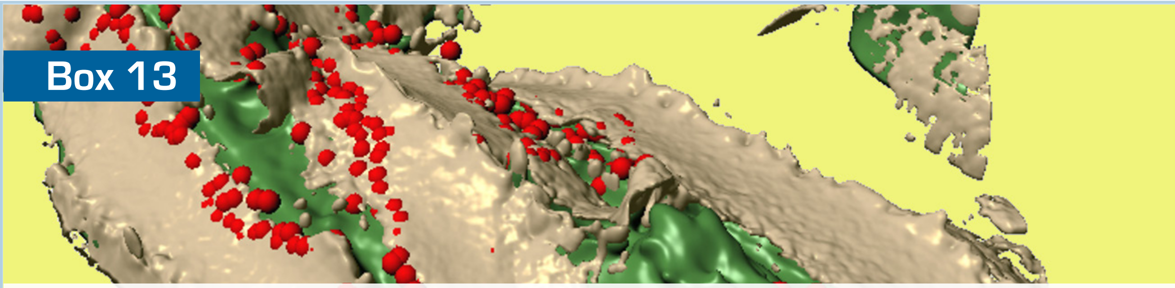
A novel process of sewage sludge hydrothermal dewatering combining biochar production

Photo © Yin Wan

Yin Wang, Xingdong Wang, Zhiwei Li, Jingjiang Lin and Guangwei Yu
Chinese Academy of Sciences, Xiamen, China

The production of sewage sludge is a growing issue in China, with 36 million tons projected in 2015. The high amounts of nitrogen, phosphorous and potassium in sewage sludge make it a prime source of supplemental agricultural fertiliser. This study developed a novel combination of processes: sewage sludge hydrothermal dewatering with biochar production. Sewage sludge can be hydrolysed and dewatered, and then pyrolysed to produce sludge biochar, which can be used as a soil supplement. Liquid from the dewatering process can be used to produce biogas to supply the hydrothermal treatment plant. Calculations for mass balance of treating sewage sludge at 100 t/d with 80% moisture were made. After hydrothermal treatment, 100 tons was reduced to 16 tons of dried sludge, and converted to 8 tons of biochar (92% reduction). The combusted gas provides 24 tons of saturated steam to meet hydrothermal treatment needs (20 t/d). Most of the phosphorous, potassium and heavy metals from the raw sludge remained in the biochar after hydrothermal treatment and stabilizing co-pyrolysis, making it a suitable fertilizer.

Box 13



Greening Environment and Economy in Surabaya, Indonesia Using Japan's Takakura Home Composting (THC) Method

Photo © Tonni Kurniawan

Tonni Kurniawan
Xiamen University, Xiamen, China

Surabaya, the second largest city in Indonesia, generates over 2,300 tonnes of municipal solid waste (MSW) daily, which is increasing by 4% yearly (2010). The MSW generated primarily consists of organic matter, with 40-60% moisture. The primary landfill is projected to reach its 10 million-tonne-limit within the next five years. Additional dumpsites will be necessary to accommodate the MSW as well as measures to reduce the amount of landfilled waste through diversion techniques like composting. In 2005, Takakura bins were introduced in Surabaya. These bins use locally available fermentative bacteria as seed compost, which reduces decomposition time from three months to only half a week. Between 2006 and 2010, over 18,000 Takakura bins were distributed to approximately 40,000 households and 8,800 sub-districts. The project involved 400 city environmental facilitators and 28,000 personnel for distribution and training. This method attained the targeted 30% reduction in organic waste. Additionally, 3,421 metric tonnes of CO_2 emissions from the landfill was avoided annually. THC is an effective method of composting that reduces production time and prevents waste from being landfilled, thereby cutting greenhouse gas emissions.

Box 14

Electric Power Generation from the Renewable Agricultural Crop Residues in Kenya

John M. Nduko
Egerton University, Egerton, Kenya

Biogas is a potential substitute for non-renewable energy sources like natural gas. Biogas production technology combines the value-addition to organic waste with the formation of methane, which can be converted to electricity. Commercial biogas production has been gaining momentum, but remains underutilised. Cow manure is currently the primary source for biogas in Kenya, yet there is a much higher biogas potential from untapped resources such as agricultural crop residues and food waste. In Kenya, one third of all the food produced is wasted. Biogas production from crop residues could serve as a means to reduce landfill waste, manage organic waste and reduce greenhouse gas emissions generated by fossil fuels. In 2015, the Tropical Power Company undertook a $6.5 million project to convert agricultural waste, specifically baby corn residues, into methane. It was the first of of its kind in Africa to utilise such biogas technology. The Company applies a 2-anaerobic digestion to complete the four-step process, which reduces production time from 50 days to 24 days. The engines produce 2.2 MW of electric power that is sold to Kenya power and supplies approximately 10,000 households. An estimated 50,000 tonnes of crop residue collected from farms will be used for anaerobic digestion for power production annually. The Company also produces 35,000 tonnes of fertiliser annually with the remaining digestate that is sold to baby corn-producing farms, thus reducing the use of synthetic fertilisers by 20%.

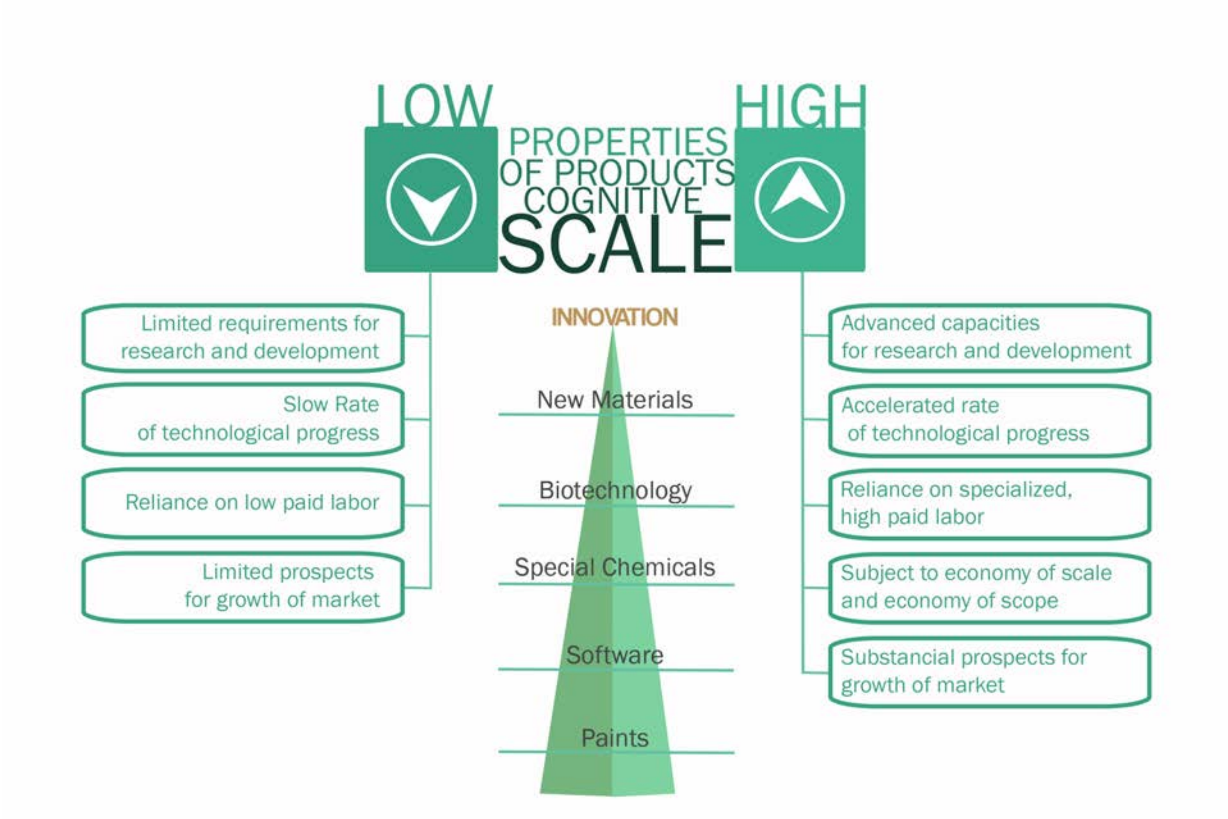


Figure 25: Product Classification According to Cognitive Content (Gaber, 2014)

reused materials (Goldsmith, 2009). Inhabitant, a blog devoted to sustainability and design, holds an annual upcycling design competition with entries coming from around the globe (Inhabitant, 2010).

Upcycling in the solid waste sector will benefit the green economy. This can be achieved by effectively managing the MSW to mitigate adverse environmental and health impacts and support green economic development and quality of life enhancement (Caribbean Youth Environment, 2015).

Table 3 shows the recyclables as substitutes of raw materials.

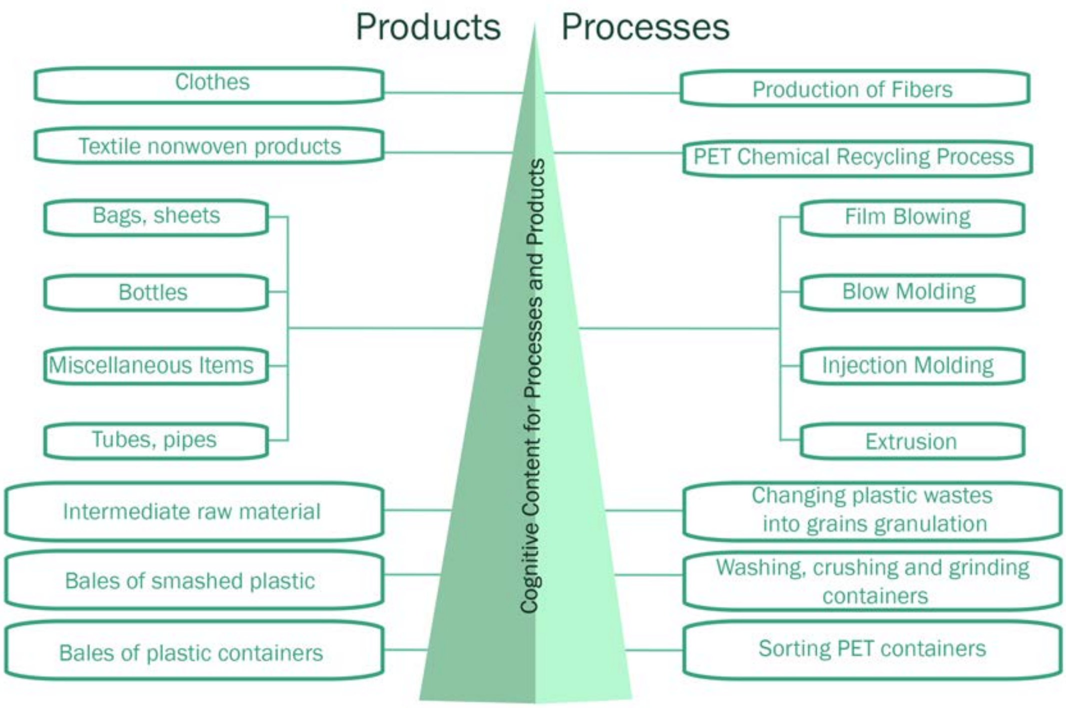


Figure 26: Recycling PET: Process and Products on Value Scale (Gaber, 2014)

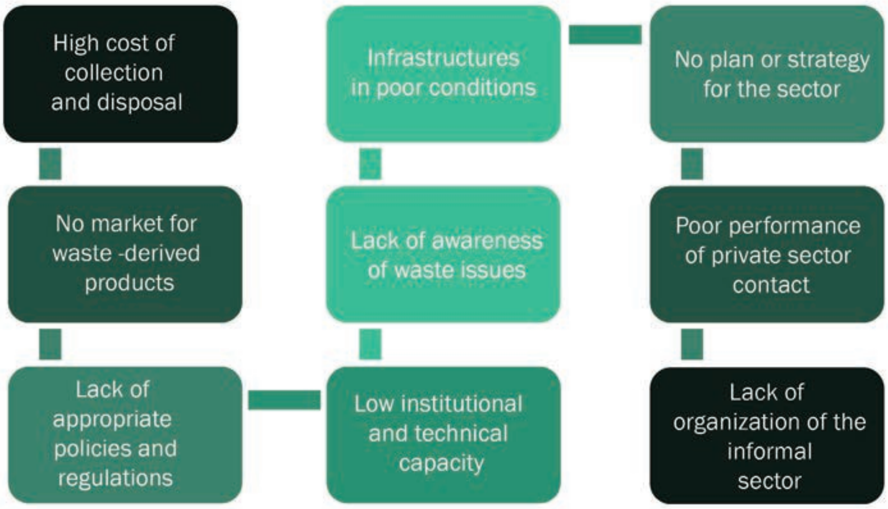


Figure 27: List of Barriers Undermining Greening the Municipal Solid Waste Sector (World Bank, 2014)

Recyclable Material	Virgin Source	Developed end uses for recycled materials	Minor, less developed end uses for recycled material
Paper Corrugated Cardboard Mixed Paper Newspaper Office Paper	Ground wood pulp Ground wood pulp Ground wood pulp Chemically pulped wood fiber, ground wood fiber	Paperboard, linerboard Paperboard, linerboard, tissue Recycled newsprint Tissue paper, printing and writing paper, paperboard packaging	Insuion, animal bedding Board mills, insulation animal bedding
Metal Aluminum Cans/foil Bulk Metal Steel Cans	Bauxite ore Iron, steel copper Tinplate steel	Aluminum beverage containers Metal mills, auto industry Steel mills	
Plastic HDPE bottles PET bottles	Petroleum derivatives Petroleum derivatives	HDPE bottles Polyester fibers (carpet, clothing)	Drainage pipe, film pallets plastic lumber Polyester fibers (carpet, clothing)
Glass Glass Containers	Sand, limestone Soda Ash	Class Containers	Fiberglass, abrasive, aggregate, fiber

Table 3: Recyclables as Substitutes of Raw Materials (NYC, 2004)

3.5. Barriers to Realising Green Economy

The issue that is creating most of the barriers towards greening the waste sector is the limited financial capacities to cope with the growing demand for good service as a consequence of fast urbanisation. Developing countries face the most acute challenges with their MSW systems. *Figure 27* shows the list of barriers and challenges undermining greening the MSW management processes in developing countries. In BRICS on the other hand, the problem is generally less intense, except in countries where waste management has been disregarded by the government. In the G8 countries, the quality of the service tends to be better, with a higher rate of municipal solid waste collection. This is due to the fact that the sector is better financed and equipped with appropriate regulatory, institutional capacity. In these countries, the trend is generally to improve the efficiency of the MSW system, and move towards a more financially and environmentally sustainable system.

In recent years, attention has focused on the limitations of waste management investments and the identification of more effective means of technology transfer. The principal barriers within countries that affect greening the solid waste sector include (IPCC, 2000):

Limited financing: Developing basic infrastructure to collect and treat MSW can be extremely expensive. Frequently, those regions where the lack of waste management is felt most severely are also some of the poorest and fastest growing. Local governments often find that they cannot generate the investment required, and availability of private financing for these types of projects can be limited, particularly if the recipient governments are not considered "credit-worthy". Investments in Waste Management Infrastructure and Services are low in developing countries. Presently, global averages are at less than 0.5%, hovering close to 0.1%

At the same time, MSW is underfunded in most developing countries. Developing countries with low income spend about US$1.5 billion per annum on MSW and expected to reach US$ 7.7 billion by 2025. *Table 4* shows an estimation of the solid waste management system by disposal method. With an existing global annual shortfall of at least US$40 billion, MSW budgets will need to at least triple over the next 20 years. Most of this funding is needed for operating MSW services, rather than for capital investments.

Limited Institutional Capabilities: Waste management systems require well-developed institutional frameworks to ensure that waste is collected as expected, disposal and treatment facilities are operated and maintained effectively, and revenues are collected.

Jurisdictional complexity: Effective waste management involves different levels of government (local, state or provincial, and national), as well as different departments within a jurisdiction. Conflicting and competing priorities can impede the efficient development and implementation of systems.

Need for Community Involvement: Ultimately, the success of a waste management system depends upon the willingness of the public to use it. Reviews of waste management projects have indicated that sustainability and performance improve to the degree that end-users are involved in the design and financing of the project. Public-Private-Partnership (PPP) is the best approach to infuse private sector capital. Weak regulatory frameworks and poor institutional capacities deter private sector investors. In addition, the largely informal nature of the sector in many parts of the world undermines much of the work to establish safe and modern waste management systems. Hence, informal sector is dominant especially in developing countries (Abaza, 2014). Mitigation projects can be successfully integrated into larger waste management efforts provided they are able to meet the needs and priorities of end-users, decision-makers, and financial supporters. However, they may confront additional barriers, including: lack of familiarity with the potential to reduce methane generation or capture the methane emissions associated with waste management; unwillingness or inability to commit additional human or financial resources to investigating and addressing the climactic implications of the waste management project; and additional institutional complexity when new groups, representing issues such as energy generation or by-product marketing, are incorporated into the project.

In order to overcome these barriers, the World Bank currently has more than 150 projects (active or under development) with waste management companies with total investment commitments of US$3.5 billion to minimise

	Developing Countries	BRICS	G8
Average Income (USD/capita)	876-3,465	3,466-10,725	>10,725
Average Waste Generation (tonnes/capita/yr)	0.29	0.42	0.78
Collection Efficiency (percent collected)	68%	85%	98%
Cost of Collection and Disposal (USD/tonne)			
Collection*	30-75	40-90	85-250
Sanitary Landfill	15-40	25-65	40-100
Open Dumping	3-10	NA	NA
Composting	10-40	20-75	35-90
Waste to Energy	40-100	60-150	70-200
Anaerobic Digestion	20-80	50-100	65-150

* Collection includes pick up, transfer, and transport to final disposal site for residential and non-residential waste

Table 4: Estimated Solid Waste Management Costs by Disposal Method (Hoornweg and Bhada-Tata, 2012)

greenhouse gases in the waste sector. The waste management projects cover the spectrum of the solid waste field – collection equipment, transfer stations, and landfill design/construction. This can help the developing countries to conquer any of the barriers that hinder greening the waste sector (WMW, 2015). In general, the World Bank's portfolio between 2000 and 2012 included 114 active projects in 58 countries in all regions, representing US$1.27 billion in investments, with a further 55 analytical and advisory activities. Bank-managed carbon funds have purchased over US$1 billion of emissions reduction credits from MSW projects which reduce methane emissions. Despite this significant portfolio, the existing US$40 billion annual global shortfall for MSW requires the World Bank to reconsider its approach to MSW and leverage innovative instruments and partnerships to increase its impact on greening the MSW sector.

4. Enabling Conditions

Long term strategies for greening the solid waste sector have been initiated by many of the G8 countries, such as Japan and the UK.

A number of essential conditions are required to enable countries to move towards that direction, such as stakeholder involvement and an enabling environment. The following section discuses a broader perspective and suggests a few powerful ideas that have emerged from a review of the policies and actions that have proven successful in promoting a green economic transition.

The enabling conditions to be adopted by countries should take into consideration the main principle guidance for greening the waste sector shown in *Figure 28.*

> The Norwegian Pension Fund Global, one of the largest sovereign wealth funds in the world, seeks to ensure that good corporate governance and environmental and social issues are duly taken into account. The fund focuses on environmental investment opportunities, such as climate-friendly energy, improving energy efficiency, carbon capture and storage, water technology, and the management of waste and pollution (GPFG, 2010).

1. Consultation and public participation: Engaging stakeholders through consultation, public awareness, participation and communication;
2. Policy Enforcement: Establishing sound legislative frameworks;

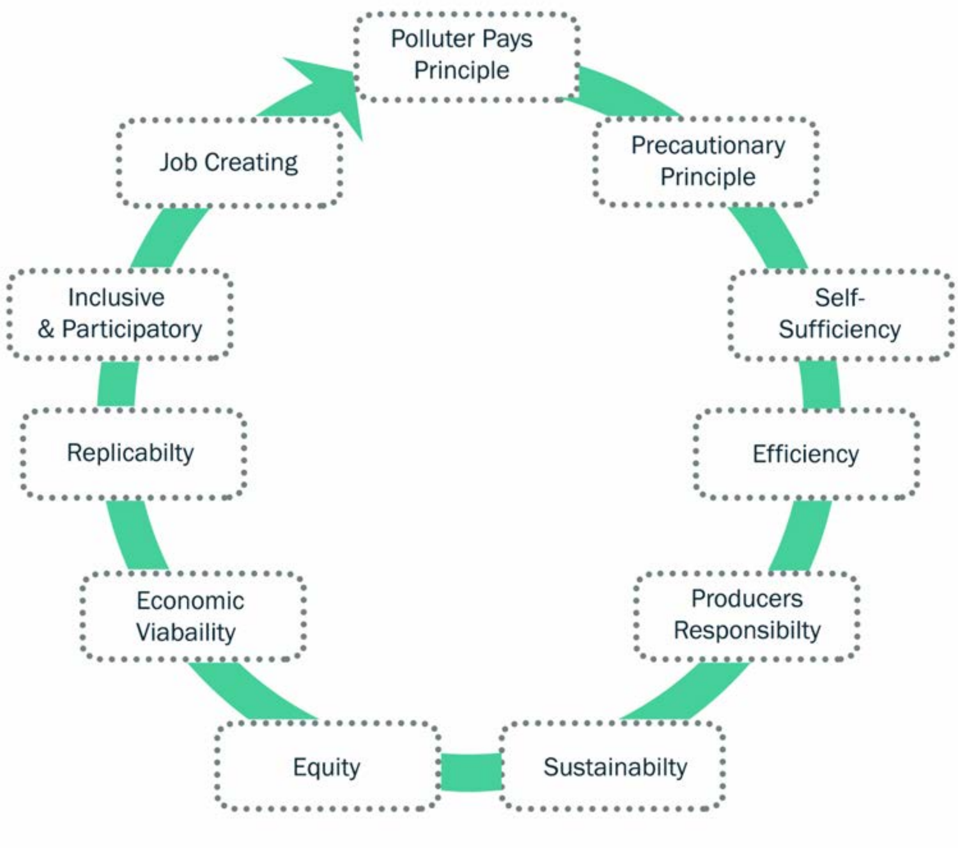


Figure 28: Principle Guidance for Greening the SWM Sector (Abaza 2014; UNEP, 2011)

3. Economic instruments: Performing economic incentives/disincentives and promoting green investment and innovation;
4. Costing and Financing: Prioritising public and private sector investment and spending in areas that stimulate the greening of the waste sector;
5. Human Resource Development: Investing in capacity building and training;
6. Innovation: Stimulating technological and social innovation to find innovative approaches to recovering maximum social, economic and environmental benefit from waste, and
7. Monitoring and Evaluation: Strengthening international governance through monitoring and evaluation.

4.1. Economic Instruments

The key thing here is how incentives and disincentives can be used to change behaviour and to correct price distortions in the market. The big problem in most developing countries is that they (i) do not charge for waste services/ disposal, or (ii) if they do, they are not charging the full cost.

The incentives in the waste sector include: 1) taxes and fees; 2) recycling credit and other forms of subsidies; 3) deposit – refund; and 4) standards and performance bond or environmental guarantee fund.

The following is a sample of incentives that may be used to green the solid waste sector:

1. Operationalise the polluter pays principle (PPP) –charging polluters according to the volume and kind of waste generated.
2. Applying the users-pays principle (UPP) – paying users of waste and its conversion to energy, by products and final products
3. Pays-as-you-throw (PAYT) –discourages waste generation.
4. Introducing labels on products that have been produced following production processes and technologies that avoid, reduce, and recycle solid waste.
5. Use of landfill taxes at proper levels or landfill disposal bans on certain materials –can encourage the reduction of waste and the 3Rs.
6. Provide incentives for industries that invest in research and development and new technologies

> The Zabbaleen minority community has been engaged in informal waste picking in Cairo, Egypt, since the 1930s. About 20,000 Zabbaleen were involved in waste-picking (30-40 per cent of an estimated 9,000 tonnes per day), recycling up to 80 per cent of the waste collected. During the 1990s, the Zabbaleen continued to work under a franchise system by paying a license fee to the Cairo and Giza Cleansing and Beautification Authorities for the exclusive right to service a specific number of apartment blocks. They collected fees directly from households (on average US$0.3 to 0.6) (Aziz, 2004)

> Nagoya city in Japan, after extensive consultation with retailing companies and two years of piloting, assigned a charge for plastic shopping bags in April 2009. The scheme was adopted by 90 per cent of the shopping market. The initiative reduced plastic-bag usage during shopping by 90 per cent as of December 2009. About 320 million bags weighing 2,233 tonnes were estimated to have been saved between October 2007 and October 2009 (UNEP, 2011).

Figure 29 summarises the incentives and disincentives of the solid waste sector.

Perverse subsidies are one of the main causes for market distortions that contribute to the inefficient allocation and use of resources and waste generation. However, the following should be considered in reforming subsidies (Abaza, 2014):

- Define and measure subsidies, as some of them may be in the form of direct financial support or reduced tariffs or charges for utilities.
- Identify perverse subsidies as opposed to subsidies that promote sustainable production and consumption patterns.
- Prepare a strategy for reforming subsidies in order to encourage measures that avoid or reduce waste generation, recycling, reuse, and recovery.

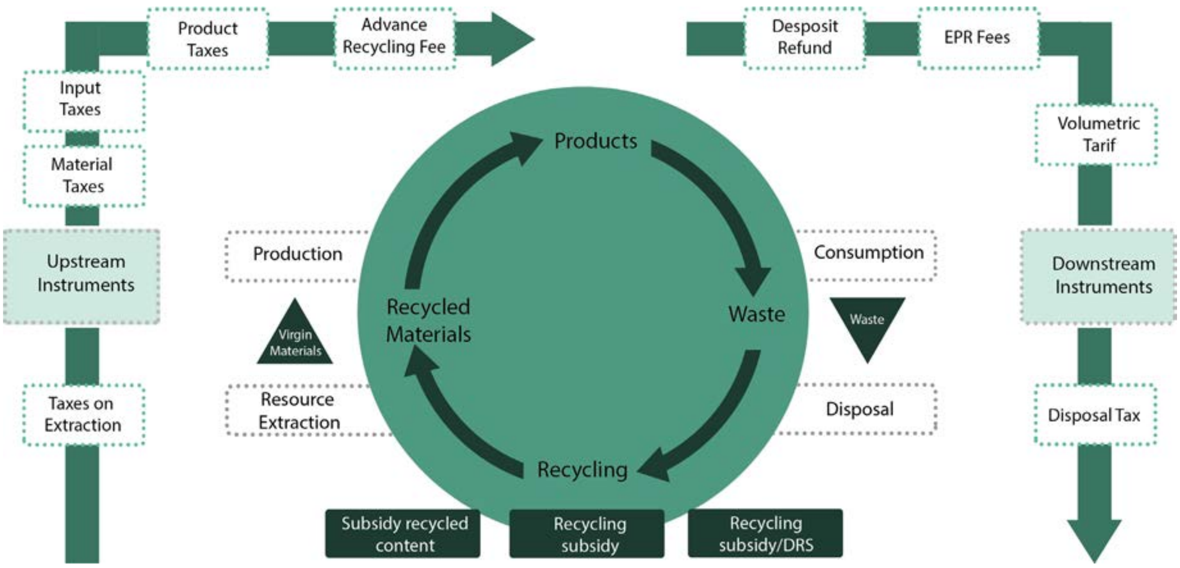


Figure 29: Solid Waste Sector Incentives and Disincentives (Council for Scientific and Industrial Research, 2014)

- Replace perverse subsidies by green subsidies. These include direct grants, loans, tax rebates or cuts to encourage investments in green sectors, including the SWM sector
- Designed as part of a package of incentives and regulatory measures aimed at reducing negative impacts on the poor, and on competitiveness
- Develop and introduce a social protection mechanism in order to address the potential resentment and negative reaction from affected parties, and the general public
- Fully monitor and consider the full implications of subsidy reform on employment and the need and importance of job creation and the need and importance of job creation

Taxes and market-based instruments can be an efficient means of stimulating investments. Significant price distortion exists that can discourage green investments or contribute to the failure to scale up such investments. In a number of economic sectors, such as transportation, negative externalities such as pollution, health impacts or loss of productivity, are typically not reflected in costs, thereby reducing the incentive to shift to more sustainable goods and services. A solution to this problem is to incorporate the cost of the externality in the price of a good or service via a corrective tax, charge or levy or, in some cases, by using other market-based instruments, such as tradable permit schemes. Taxes often provide clear incentives to reduce emissions, use natural resources more efficiently and stimulate innovation. Environmentally related taxes can be broadly broken down into two categories: “polluter pays” focused on charging producers or consumers at the point that they are responsible for the creation of a pollutant; and “user pays”, which focuses on charging for the extraction or use of natural resources.

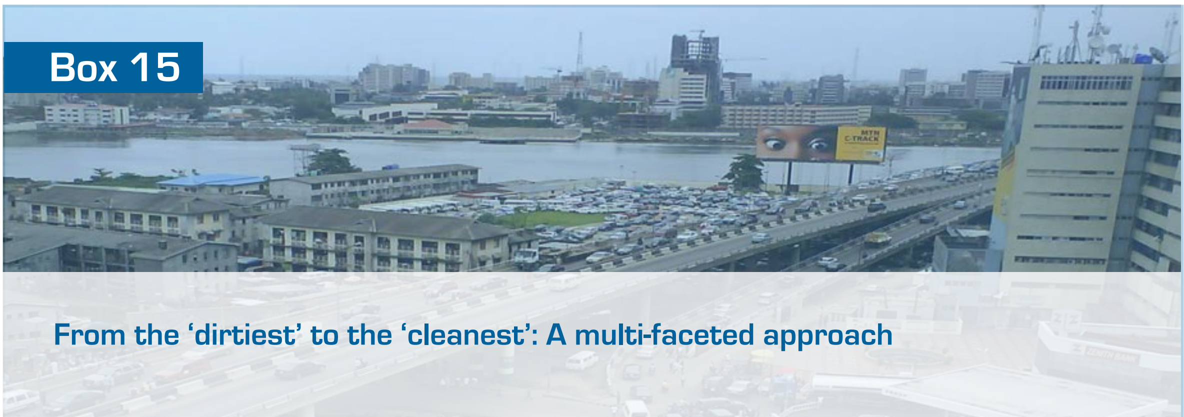
4.2. Costing and Financing

Proper MSW management systems may appear expensive compared to the less visible costs of poor waste management, yet equitable compromises between costs and social benefits (i.e. job creation, added value, mitigating environmental negative impacts, alleviating health risks and improving the quality of life) are needed. An underlying cause of the difficulty associated with MSW management is the economy of scale of most waste management facilities.

4.2.1 Role of the Private Sector

The active involvement of the private sector and promotion of public-private-partnership through finance and expertise is critical for greening the SWM sector. Governments need to provide the right regulatory and market incentive measures to achieve this. Several countries across the G8, BRICS, and developing countries have been privatizing the SWM sector as a means of upgrading services provided. A case study in Lagos,

Box 15



From the ‘dirtiest’ to the ‘cleanest’: A multi-faceted approach

Photo © Samuel Sojinu

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Lagos State, Nigeria earned the title of the “Dirtiest Capital City in the World” in 1977. The government has since implemented a multi-faceted approach to solid waste management. Firstly, the Lagos State Waste Management Authority (LAWMA) was initiated to collect and dispose of waste. Over the next 30 years or so, LAWMA underwent a number of changes involving private sector participation and government-appointed operators, culminating in the state winning a National Award for Best Practices for Improving Living Environment. In 2005, the state restructured LAWMA in preparation for a World Bank-funded project. Since then, LAWMA has managed industrial and commercial refuse and supervises over 116 PSP operators. A myriad of SWM methods were employed in Lagos, owing to its success. These include: curbside pickup, communal depots, and various container systems (i.e. block, hauled and stationary).

Nigeria is shown in *Box 15*. However, before going down this road, governments should lay the ground rules and responsibilities for private sector involvement to ensure an acceptable level of provided services (Abaza, 2014).

Voluntary initiatives should be encouraged in order to influence attitudes towards the environment. Public-Private-Partnership can be applied in a number of forms, including as service contracts clearly identifying the types of service to be provided by the private sector. Management contracts, on the other hand, cover activities such as operation and maintenance, with investments being the responsibility of the public partner.

4.2.2 International Funding

Multilateral Environmental Agreements (MEAs) lead to the creation of specific funds that can support initiatives lead to greening the waste sector.

In this process, aspects of product discards and waste management get addressed. ICF (2008) suggests that while non-Article 5 countries[1] use ODS levies (e.g. tax per kg of refrigerant imports/production), municipal taxes, and taxes on new equipment, A5 countries could use direct assistance from the MLFs, and/or through appropriate carbon trading platforms such as CDM for implementing an approved ODS destruction methodology. MLFs could consider co-funding incremental costs associated with the removal

[1] Developing country parties to the Montreal Protocol whose annual per capita consumption and production of ozone-depleting substances (ODS) is less than 0.3 kg. These countries are eligible for assistance under the Financial Mechanism (including the Multilateral Fund for the Implementation of the Montreal Protocol), which was established by a decision of the second Meeting of the Parties to the Montreal Protocol (London, 1990) for the purposes of providing financial and technical cooperation, including the transfer of technologies, to the „Article 5“ countries to enable their compliance with the control measures of the Protocol. For a list of the countries belonging to this group, see: http://bit.ly/swm01

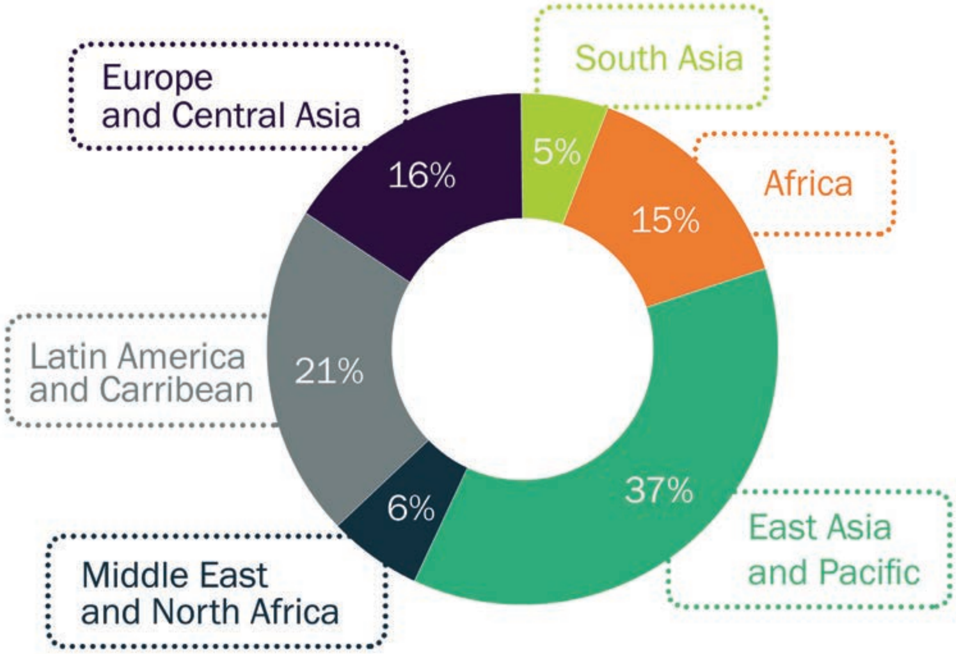

Figure 30 shows the World Bank's estimations in the investment in the MSW management across the world

and destruction and/or recovery and recycling of ODS refrigerant and foam from appliances, or finance the disposal of older appliances. Figure 30 shows the World Bank's estimations in the investment in the MSW management across the world.

4.2.3 Cost Recovery from Users

Waste services are provided as public services in many countries. Payments for waste collection and transport services by households, enterprises, and large-scale industrial installations, for example, can help recover the capital cost and defray the operational costs.

Cost recovery is a strategy to generate funding for investing in greening the waste sector. It has the potential to shift the costs of environmental and public health management – including administrative, capital, and operational costs – to waste generators allowing for more appropriate sharing of costs following the polluter pays principle. Also, one important side benefit is that putting a price on waste for consumers incentivises them to generate less waste. Cost-recovery measures can include administrative charges and fees covering the establishment and maintenance of registration, authorisation or permitting systems and user charges and fees for publicly provided waste collection, treatment and disposal services.

Environmental liability measures or environmental fines can also be designed in a way that helps ensure that the cost of remediation and clean up as well as the environmental health cost is covered by the negligent parties, i.e. the polluters who are responsible, rather than drawing resources from public budgets.

4.2.4 Innovative Funding Mechanisms

Micro-financing and hybrid financing are particularly useful innovative financing mechanisms for supporting small-scale efforts. The "Participatory Sustainable Waste

Management Project" established in Brazil in 2006, for example, created micro-credit funds from donations (Hogarth 2009). These funds are used as working capital for financing waste transportation and waste-related emergency responses. The funds are also used to extend loans to waste scavengers who will repay their loans after receiving payment from recycling depots.

Hybrid financing models (combining debt and equity) are being increasingly explored to support economically challenged waste management projects. Examples exist from the early 2000s in the UK, when the British government introduced prudential borrowing which gave municipal councils more freedom to borrow, removing any restriction on how much debt they could run up.

Eco-entrepreneurship is another potential to encourage small and medium enterprises (SMEs) to be engaged in the MSW practices. Eco-entrepreneurship can help in solving environmental problems through the market by identifying environmental challenges and reinterpreting them as market gaps. This aims at reducing the environmental negative impacts from one side and turns those gaps into business opportunities. One such challenge relates to the falling availability of natural resources on the one hand and rising material costs on the other (Switch-Asia, 2013a). There are many business opportunities are available in MSW management for SMEs to invest as eco-entrepreneurs and to turn “trash to cash”. Such opportunities include sorting for recycling, battery recycling, waste processing and renewable energy solutions (Entrepreneur, 2015).

A good example for Eco-entrepreneurship is the Malaysian Biomass Initiative (MBI). The promotion of biomass products drives the green technology sector and helps mitigate global climate change. SMEs are turning this biomass into various value-added products such as bio-chemicals, bio-fuels, bio- feedstock (raw materials) and bio-resources (Switch-Asia Impact Sheet, 2013b).

4.3. Human Resource Development

Training and skill enhancement programs are needed to prepare the workforce for a green economy transition. A shift to a green economy by definition entails some degree of economic restructuring, and measures may be required to ensure a just transition for affected workers. In some sectors, support will be needed to shift workers to new jobs. Investing in the re-skilling of the workforce may also be necessary.

Education systems in the BRICS and developing regions need to be revamped to produce an education curriculum that meets current and future challenges. University and vocational curricula should cater for current and future market demands. Sustainability tools and methodologies should be introduced and taught at schools, universities and training centres. Moreover, education systems should be geared towards encouraging innovative thinking, research and development.

At global level, overall investment in research and development and deployment of technology are in the range of US$ 12.5 billion annually both by the private and the public sectors. National capacities to absorb and develop appropriate and environmentally sound technologies are key to making the transition to a Green Economy and in achieving sustainable development. Funds allocated for R&D for developing countries are about 0.15% of GDP as compared to the world average of 1.4%, and 2.5% in Europe. Developing countries should therefore make adequate budgetary allocations available for R&D. Government should encourage investment by the public and private sector in research and development and technological development in SWM to support the greening of the sector.

4.4. Monitoring and Evaluation

Monitoring and evaluation should be part and parcel of the planning, decision-making and implementation processes. They are intended to ensure that the proposed polices are achieving their set objectives through the introduction of necessary corrective measures and actions, as appropriate. Capacities of developing countries, in particular, to develop follow up, monitoring and evaluation tools and techniques are needed to ensure that policies, plans, and programs are on target and are yielding the desired outcomes. This process should set criteria and timing for monitoring and assessment.

Overall monitoring and assessment should be the main responsibility of the central government at national level. However, it should be the responsibility of municipalities to monitor and assess the implementation of strategies, policies, and action plans at national level.

5. Conclusion and Recommendations

Increasing solid waste quantities are posing threats to the ecosystem and public health. Finding proper sustainable solid waste management strategies is a vital need to mitigate the environmental and health problems. In addition, proper MSW management will contribute to alleviating poverty through creating jobs. Moving towards a green economy in the solid waste sector has the potential to achieve many of the SDGs particularly: Goal 1- No Poverty; Goal 3 – Good Health and Well Being; Goal 7 – Affordable and Clean Energy; Goal 8 – Decent Work and Economic Growth; Goal 11- Sustainable Cities and Communities; Goal 12 – Ensure Sustainable Consumption and Production Patterns; Goal 13- Climate Action; and Goal 17 –Partnership for the Goals

Opportunities for greening the waste sector exist in the form of preventing waste in the first place, followed by the "three Rs": reuse, recycle, and recovery. The transition to greening the waste sector is driven by creating new jobs, minimising greenhouse gases emissions, returning valuable materials to the productive economy, improving the quality of life, mitigating the public health impacts and generating electricity.

Solid waste management challenges vary from region to region, with many differences in terms of the quantity and composition of waste as well as currently adopted practices. However, the path to greening the waste sector shares common milestones. Prevention and reduction of waste at source should be a high priority for all countries, and this is particularly important in developing countries, given their higher level of population growth and increasing material and resource consumption. Greening the solid waste sector is an important step towards decoupling economic growth and resource consumption. The integration of proper waste management systems can reduce pressure on natural resources, as well as improving human and environmental health outcomes.

The opportunities for greening the waste show a lot of environmental and socioeconomic benefits, although there is no one-size-fits-all approach. It is crucial that emerging and developing countries carefully consider the appropriateness of alternative waste treatment technologies, so that they don't get locked into technologies which may be more complicated for them. The BRICS and developing countries should therefore come up with their own visions and strategies for greening the SWM sector that result in Savings in energy and natural resource, Creating Jobs and new business opportunities, Reducing GHG emissions and Improving health and socioeconomic conditions.

Proper collection, segregation, transport and recycling of waste as well as the construction of basic facilities are essential steps in many developing countries. It is therefore crucial to ensure that stringent regulations are in place and comprehensive environmental policies addressing the necessity of recycling and reducing landfills are developed. The waste recovery and recycling part of the waste treatment chain probably holds the greatest potential in terms of contributions to a green economy.

When planning their treatment facilities, developing countries may want to take into consideration the potential growth of resource and energy recovery as an increasingly significant industry. One of the most important advantages of greening the waste is to involve formalisation of the informal scavengers sector in many developing countries. Accordingly, it is highly recommended to provide proper training, health protection, and a decent level of compensation for the informal waste scavengers. This could be carried out by governments and non-governmental organisation (NGOs). Therefore, greening the solid waste sector will contribute to improving equity and poverty alleviation.

Mobilising investment into greening the waste sector requires a number of enabling conditions. Governments should increase their budgetary allocations to the sector. Further, entering into partnerships with the private sector has the potential for reducing fiscal pressure while enhancing the efficiency of service delivery. International development assistance and other financing mechanisms can also be explored to support localised waste treatment systems that provide employment opportunities for local communities while reducing the need for distant transport of waste.

For developing countries and BRICS, the paramount aspect should be sustainable waste management practices – city cleansing, service delivery, properly managed landfills. Once they have this, they can explore opportunities in materials recovery (composting, recycling and WtE). With this come to increasing costs; exploring alternatives and charging appropriately for these services might be needed. As waste generators become used to paying, and as costs increase, alternative waste treatment technologies can be explored, such as anaerobic digesters, incineration and WtE. Countries must find solutions that are appropriate to them, that unlock the greatest social and economic value from waste as a secondary resource. They must take care not to get locked into technologies that are not appropriate, are costly, and for the maintenance or operation of which they don't have skilled expertise.

Greening the waste sector requires policy framework, economic incentives and financing. It is proposed that the role of the central government be confined to developing policies, data gathering, assessment and analysis as well as capacity building, monitoring and evaluation, while giving municipalities the role of adapting the policies and action plans according to local needs and priorities. In countries with weak governance structures, engaging the communities and the private sector might be a preferred option.

This report sets several recommended actions to be taken into consideration in both the short and the long term, especially for emerging and developing economies. These recommendations will aid to greening the waste as well as achieving the main SDGs related to the waste sector. The actions are:

- Create platforms where different stakeholders can meet and learn in collaboration. Such platforms are needed both inside and outside the formal educational system. Enhancement of public participation and consultation would be effective in advancing SWM practices.
- Provide a well-thought, detailed and clear policy developed by a government that is committed to its implementation nationwide in order to turn towards green economy in the waste sector. An appropriate policy and strategic framework needs to be developed, together with technical guidelines to properly guide local bodies in effective SWM.
- Establish a comprehensive, integrated, harmonious plans at sectorial and geographical levels in accordance with the 3Rs (Reduce, Reuse and Recycle). The 3Rs should be promoted. The report identified great potential for resource recovery in developing countries, which could be realised with better public awareness and initiatives by local bodies and communities.
- Conduct a package of tools for enforcement and compliance: legal, economic, communication and outreach tools. In addition, strengthening the capacity of local bodies is essential, as they are mandated to provide SWM services to the citizens.
- Current poor management practices such as open dumping and open burning, should be stopped immediately to allow for more integrated SWM.
- Conduct mechanisms and programs for finance, financial support and technical support. This support should also improve the management, updating and dissemination of basic data provided it will play an important role in improving planning by the local bodies and in monitoring implementation progress.
- Accelerated innovation is vital to meet our shared, long-term SDGs. Through the contribution of technological innovation to fostering economic growth and the need to incentivise investments in safe and sustainable waste treatment technologies, the use of a range of available policy options, such as policies to support research, development, and demonstration (RD&D), is required.
- Conduct further research and studies in each region to identify the health damage costs and benefits in the solid waste sector. The potential of health benefits as a result of greening the municipal solid waste sector should be studied thoroughly as a significant socioeconomic positive impact on the affected societies. Hence, alleviating serious health issues, such as HIV and hepatitis, will be a significant economic added value for communities.

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