CIRCULAR ECONOMY FOR COST-EFFICIENT WASTE UTILIZATION, ANALYSIS FOR GUJRANWALA AND BAHAWALPUR

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CERTIFICATE

This is to certify that this thesis entitled: **Circular Economy for Cost-efficient Waste Utilization Analysis for Gujranwala and Bahawalpur** submitted by **Ms. Saima Bashir** is accepted in its present form by the School of Economics, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the requirements for partial fulfillment of the degree in Master of Philosophy in Environmental Economics.

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Author's Declaration

I **Saima Bashir** hereby state that my MPhil thesis titled **Circular Economy For Cost-Efficient Waste Utilization, Analysis For Gujranwala And Bahawalpur** is my own work and has not been submitted previously by me for taking any degree from Pakistan Institute of Development Economics or anywhere else in the country/world.

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Abstract

Pakistan's per capita municipal solid waste ranges from 0.283 to 0.612 kg/day. Statistics suggest that Pakistan emitted 490 million tons of CO_2 equivalents in the year 2017-2018 where 4% was contributed by waste sector. Increased population burdens the already struggling resources of solid waste management in the cities, and at the same time, changing consumption and production patterns is leading to newer waste streams such as plastics, electronic waste, or hazardous chemical wastes for which effective and efficient waste management processes have yet to be firmly implemented.

Throughout the world, concepts like circularity, Waste to Energy or Circular Economy are being popularly explored to socially, economically and environmentally benefit from it. This model leads us to two areas of research that this study will cover. First, the study will aim to explore economically feasible waste management solutions for waste managed by formal and informal waste sectors in Pakistan's context. Secondly, the study will explore the options for creating a legislative environment for piloting the circular economy.

The study finds that waste composition of Bahawalpur and Gujranwala have highest percentage of organic waste followed by Plastics and paper. All these categories have high circularity potential where the cost-benefit analysis shows that the most feasible technology for waste that ends up in open dumps is gasification followed by pyrolysis and incineration. Unmanaged waste percentage for Bahawalpur and Gujranwala reflects the lack of capacity of public institutions to manage city waste. The study also identifies and suggests measures to create an enabling environment for Pakistan to transition to a circular economy model. This will require the participation of all the actors in the value chain as well as the decision-makers, donors and researchers. The recommendations include the role of public sector to create an ownership and gather consensus of the larger audience, supporting legislations like levy on fossil fuels, creating standards for recycled products, green purchasing policy for public sector, etc., disseminating the information on grants, direct and indirect investments for filling the financial gap, leveraging Public-private partnerships, education, awareness and training of government, businesses, and society and monitoring progress.

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3Rs	Reduce, Reuse And Recycle
δ	Discount rate
ADB	Asian Development Bank
C/N	Carbon to Nitrogen ratio
CAP_k	Investment cost for technology
C_k	Operational costs
CBA	Cost Benefit Analysis
CEAP	Circular Economy Action Plan
CGPM	Clean Green Pakistan Movement
CoRe	Collect and Reuse alliance
DMC	District Municipal Committee
EPA	Pakistan Environmental Protection Agency
EPR	Extended Producer Responsibility
EU	European Commission
GHG	Greenhouse gas
IETC	International Environmental Technology Center
ITA	International Trade Administration
KP	Khyber Pakhtunkhwa
kWh	Kilo Watt hour

LCA	Life Cycle Analysis
LG&RD	Local Government and Rural Development Department
LHV	Low Heating Value
LWMC	Lahore Waste Management Company
MIWL	Municipal and Industrial Waste Levy
MoEF	Ministry of Environment and Forests
MSW	Municipal Solid Waste
MWh	Mega Watt Hour
NAP-SCP	National Action Plan on Sustainable Consumption and Production
NCPC	National Cleaner Production Center Foundation
NCV	Net Calorific Value
NDC	Nationally Determined Contributions
NEPRA	National Electric Power Regulatory Authority
NPO	National Productivity Organization
PHED	Public Health Engineering Department
PKR	Pakistani Rupees
PPP	Public-Private Partnerships
PSQCA	Pakistan Standard and Quality Control Authority
REAL	Resource Efficiency through Application of Life Cycle Thinking
SDG	Sustainable Development Goals
SSWMB	Sindh Solid Waste Management Board

SWM	Solid Waste Management
T_k	lifetime of WtE technology
TF	Tipping Fee
WASA	Water and Sanitation Authority
WSSP	Water and Sanitation Services Peshawar
WtE	Waste to energy

Chapter 1 Introduction

According to the World Bank, a 70% increase in waste generation is expected by the year 2050 as compared to the 2016 levels (Silpa Kaza, 2016). Patterns of waste generation have increased as a result of swift development and urbanization globally and Pakistan is no exception. Pakistan is a developing country undergoing rapid population growth and industrialization. While economic growth and progress sees both highs and lows, there is an uglier truth that persists as a parallel factor of such development: the rising giant of waste. Solid waste generation increases with a rate of 2.4% annually in Pakistan - equal to its average population growth rate.

Waste generation in Pakistan has risen exponentially. Poor management is affecting rural and urban areas alike, increasing incidence of disease and polluting the air. In Karachi, the piles of waste are overshadowing the exuberance and the glory that once earned the city the title of the 'City of Lights'. Similarly, Lahore is experiencing a worsening situation of waste mismanagement, as two of the city's landfill sites have reached capacity. Without proper systems, the waste remains uncollected and scattered in streets, in vacant plots, or in water bodies (Imran, Karachi – where garbage is piling up, 2019). Daily waste generation in major cities of Pakistan is shown in Figure 1.1.

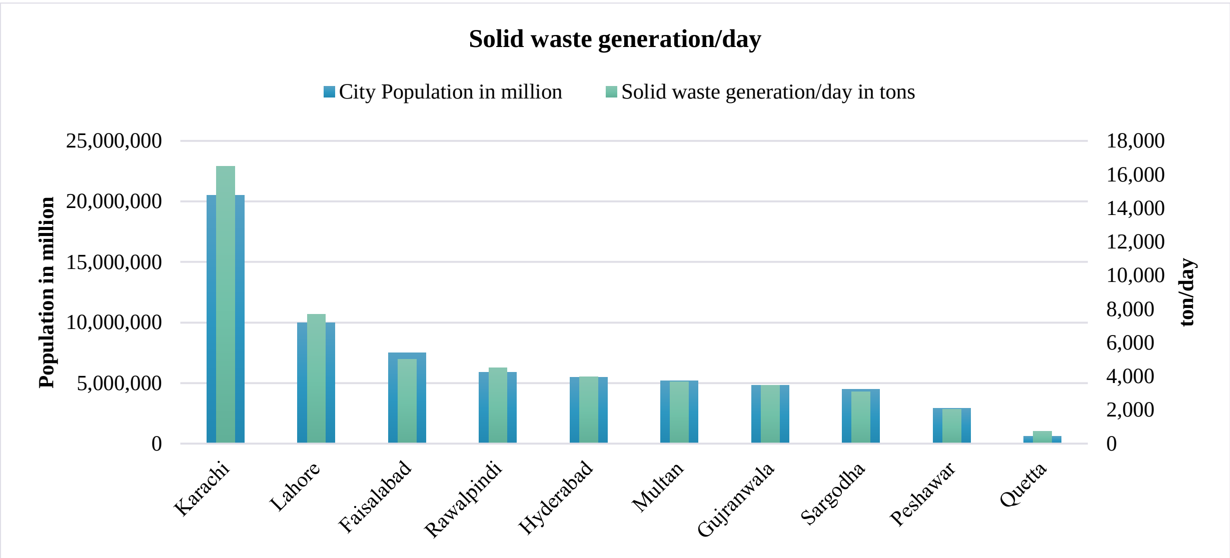

Figure 1.1 Daily solid waste generation in Pakistan's provincial capitals

Source: (ITA I. T., 2022)

Pakistan's per capita municipal solid waste ranges from 0.283 to 0.612kg/day (Salam, 2021) (Punjab, 2018). Plastic waste alone makes up 3.3 million tons of the total waste collected per year (Gul, 2020).The bulk of this waste comes from the major cities and metropolitans of Pakistan like Lahore, Karachi, Faisalabad, and the Islamabad Capital Territory.

While these cities are the hotspots of economic activity, they are also the areas that most attract human settlements from surrounding rural and smaller urban localities. Increased population burdens the already struggling resources of solid waste management in the cities, exacerbating management problems. At the same time, changing consumption and production patterns are leading to newer waste streams such as plastics, electronic waste, or hazardous chemical wastes for which effective and efficient waste management processes have yet to be firmly implemented. Moreover, the rate of waste generation is considerably high considering the country's scarce resources for management. Pakistan ranks fifth in the South Asian region in terms of per capita Municipal Solid Waste (MSW) generation. Here, the average waste generation rate is 0.43kg/capita/day, out of which only 50-60% is collected (Sohoo, 2021).

1.1 Institutional system of waste management in Pakistan:

Waste management is a provincial subject in Pakistan where the Local Government and Rural Development Department (LG&RD) are tasked with overseeing the waste management activities. Institutes responsible for waste management are city waste management companies or municipalities that collect the waste from garbage points or via door to door collection and take it to the final destination sites. In large urban centers, privately operating waste management companies are greatly involved in waste collection, its transport, and the recycling activities related to it.

Public institutions and bodies involved in waste management in Pakistan are shown in the Figure 1.2.

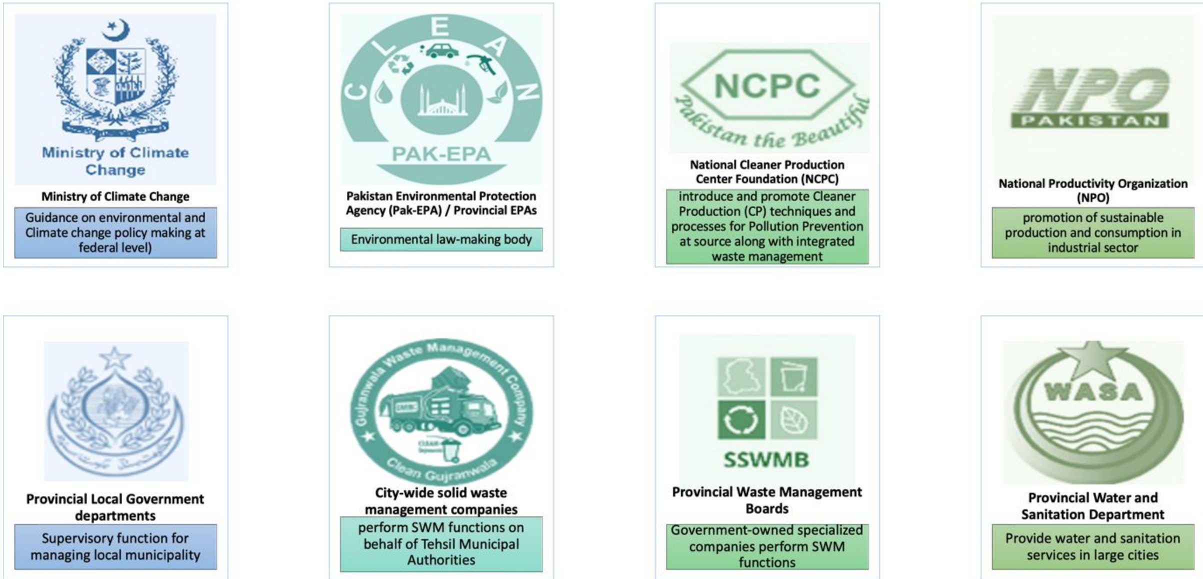

Figure 1.2 Public institutions for waste management in Pakistan and their roles

Source: Compiled by Author

The public sector responsible for waste management faces number of issues that limits their performance. Thes include lack of integrated waste management plans for urban and rural areas, weak regulations and their ineffective implementation to control the solid waste, limited technical education, human resource and technology/equipment to manage the waste, absence of occupational health and safety standards and limited budget allocations for waste sector.

1.2 Pakistan's efforts to strengthen waste management:

In recognition of the multitude of problems posed by improper waste management, several efforts have been made to align the development in this regard. These efforts have included the development of policies as well as the signing of international agreements.

Pakistan has put due focus on waste management when developing its Nationally Determined Contributions (NDCs) to limit greenhouse gas (GHG) emissions and the impact of climate change. The GHG emissions of Pakistan are low in comparison to other countries utilizing fossil fuels as their primary source of energy, as Pakistan relies heavily on natural gas instead of coal. Statistics suggest that Pakistan emitted 490 million tons of CO_2 equivalents in the year 2017-2018, which is quite low compared to the developed countries statistics (Ministry of Climate Change Pakistan, 2021). The GHG emission percentages are presented in the form of a pie graph in Figure 1.3.

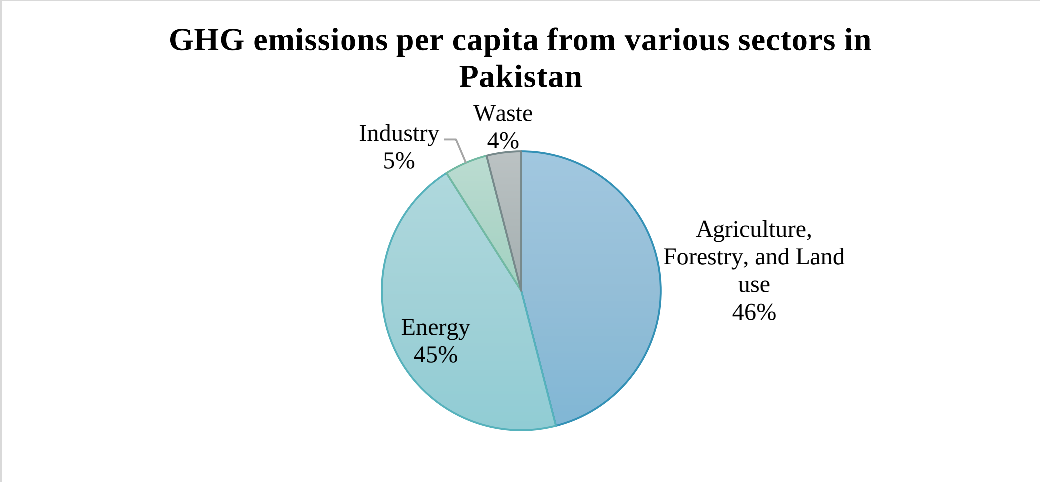

Figure 1.3 Greenhouse gas emissions of Pakistan by sector

Source: (MoCC, 2021)

Working on its NDCs, Pakistan has developed a multi-dimensional approach to reduce waste and improve sanitation and hygiene within its cities. The NDCs are also focused on reducing the overall waste generation, and on encouraging the reuse and repurposing of existing products to prevent them from ending up in a landfill. Although the waste sector of Pakistan is responsible for the lowest levels of emissions, there still remains the need for an improved national sanitation and waste collection system to fight the environmental hazards caused by mismanagement. For example, methane produced from landfills can be used as biofuel in transportation systems such as Karachi's Bus Rapid Transit project. Within the updated Pak-NDCs there is a special focus on promoting the three 'R's' for waste management: Reduce, Reuse And Recycle. Objectives for waste infrastructure are also set.

Other projects such as the flagship project of Clean Green Pakistan Movement (CGPM) is encouraging cities to improve their conditions with respect to the five pillars, namely; drinking water, solid waste management, sanitation, hygiene, and plantation cover. The CGPM project is mobilizing citizens and local governments to achieve their targets, for city development, under these five pillars (GoP, 2021). The pillar of solid waste management in particular deals with household coverage for solid waste collection in each city and the improvement of infrastructure for solid waste management. The waste management measures issued under the National Climate Change Policy 2021 by the Ministry of Climate Change (MoCC) suggest that digitization of urban planning and the waste collection system could result in efficiency gains. Digitization would mean integrated SWM systems would be prioritized at every level, provincial and local, with an emphasis on the separation of recyclable waste at collection points to conserve resources. Raising awareness within communities about the hazardous effects of plastic and other waste to reduce usage is another strategy that needs to be thoroughly implemented (MoCC, 2021).

Efforts have also been made to manage newer waste streams such as plastic. In Islamabad, a total ban on manufacture, distribution, sale, and purchase of Bannon-degradable plastic bags had been implemented under the MoCC's Single-use Plastic Ban. Heavy fine imposition has been suggested to discourage people from using polythene bags in their routine dealings (Hussain, 2019). According to a 2018 report by Pakistan EPA, the current usage of plastic bags has reached 55 million, which has choked around 80 percent of the storm drains causing flooding. Their burning meanwhile releases toxic chemicals in the environment which is harmful for human health and thus is not a viable solution. (News Desk, 2019)

Similarly, individual efforts are also in play to manage waste streams. For example, Collect and Reuse (CoRe) alliance along with Ministry of Climate Change hosted a stakeholder convention to encourage dialogue regarding the shared challenges of packaging waste, and the collection mechanism in the country in 2021. The dialogue proved to be the first step towards developing a circular economy for packaging waste (CoRe, 2021).

Lastly, multilateral efforts to cater to the problem of hazardous waste have been made; several international agreements have been signed by Pakistan. These agreements are based on chemical waste as well as organic pollutants. The Basel Convention on the control of trans-boundary movements of hazardous wastes and their disposal is in effect in Pakistan. The purpose of the agreement is to focus on the development of inventories of hazardous waste and downstream hazardous waste management capacity in Pakistan. The aims of the agreement extend to hazardous waste assessment studies, development of business cases/plans to assist government and industry to establish the requisite infrastructure. Other than that, Pakistan is also signatory to Rotterdam Convention and the Stockholm Convention that deal with the import and export of hazardous and chemical wastes (Multilateral Environmental Agreements (MEAs), 2022).

1.3 Mismanaged waste, more than just a cleanliness issue

It has now become increasingly apparent that waste might very well be an unavoidable consequence of human activity. However, as unavoidable as it may be, it is certainly not unmanageable. If left unattended, waste gives rise to a multitude of problems extending to environmental, developmental, and health issues, all of which Pakistan has experienced. For example, the waste that lies scattered, pollutes water bodies and clogs drains and sanitation systems as waste enters the pipeline. This creates massive environmental challenges. These circumstances resulting from the mismanagement of waste worsen during climatic events such as floods. During a flood episode, the scattered waste that remains uncollected, or is not deposited at its final destination after collection, is carried with the water into the drainage systems and water bodies. As a result, drainage systems and sanitation systems experience clogging, and the water that remains stagnant causes disease and bad odor. Additionally, the waste carried into the water bodies then pollutes rivers and lakes, effecting marine life. At the same time, these circumstances also attract a plethora of vector borne diseases such as diarrhea. This situation has become so dire in Pakistan that almost five million people die each year due to waste related illnesses (Javaid, 2019).

While national frameworks and policies including Pakistan's NDCs, Pakistan's Approach to Total Sanitation, and the Pakistan Sanitation Policy stress heavily on development of robust and integrated waste management systems, the implementation of them is currently low. The reasons for which are clustered under low institutional capacity, insufficient and outdated waste management infrastructure, development of newer waste streams, bureaucratic issues, and lack of awareness regarding harms associated with waste mismanagement among the population (ITA, 2022).

Waste management is a key factor in building sustainable and livable cities. The changes in consumption patterns of the growing population burden the weakly managed infrastructure particularly in developing countries like Pakistan. As a result, interest towards innovative management solutions is increasing. Throughout the world, concepts like circularity, Waste to Energy or Circular Economy are being popularly explored. The "Circular Economy" model in contrast to linear model of "take-make-waste", allows nations to explore and adopt a system to reusing waste as a raw material rather than extracting virgin resources. In this way all of waste categories including organic, plastic, glass, clothes, etc. become the part of the economy. Within the circular economy model, focus is shifted from the consumption and disposal of materials to their conservation and reusage along with extending the longevity of the materials (Figure 1.4).

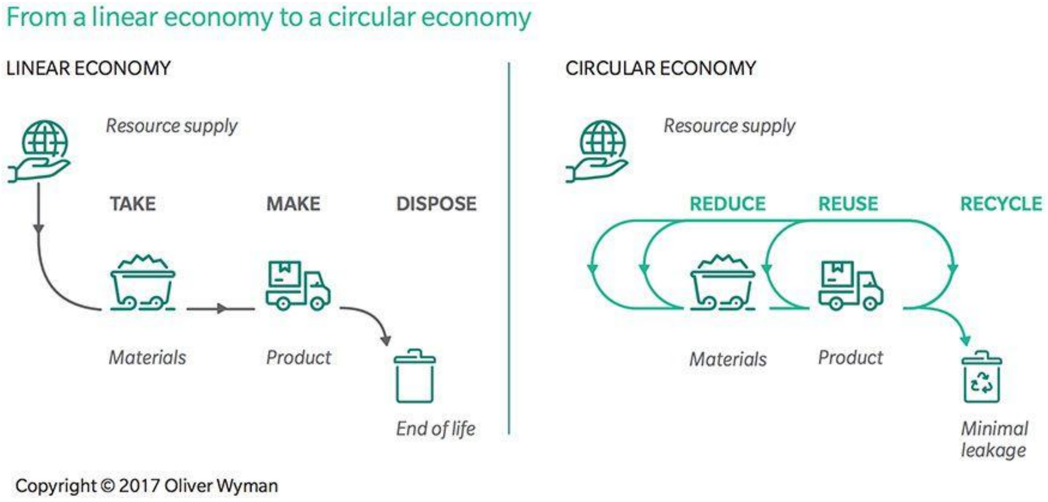

Figure 1.4 Linear Vs Circular Economy

The benefits of a circular economy range from environment to economic and social. The model is an outcome of concerns for ecological systems where the aim is to conserve the environmental resources (air, land and water) for future generations. Circular economy allows lesser GHG emissions and preservation of natural resources. EU estimates that its emissions from industrial sector will fall by 56% by 2050 if circular economy becomes a reality (Economics, 2018). Similarly, in another study, EU estimates that there is a potential of reducing artificial fertilizers consumption by 80% from food systems if circular economy is realized (Ellen MacArthur Foundation, Intelligent assets: Unlocking the circular economy potential, 2016). The benefits of circular economy also extend to socio-economic dimension where circular economy has the potential of USD 4.5 trillion economic opportunities by 2030 by stimulating reduction in waste, boosting innovation and generating livelihood opportunities (Peter Lacy, 2015).

The success of such initiatives is highly dependent on effective and context-specific evidence generation. However, in Pakistan, the data is lacking which makes it difficult to design and implement such models. The data available from secondary sources such as the CGPM and the city data provided by Provincial EPAs could be utilized to develop an economic analysis for developing a circular economy model based on existing waste streams, which can be divided based on the nature and material of waste and what treatment processes can be applied. Important waste streams or categories are:

Figure 1.5 Important waste streams or categories

Source: (GOV.SI, 2022; Hosseinalizadeh et al., 2021)

1.4 Research Objectives and Problem Statement:

The problem statement that the research focuses to find answer for would be:

The average waste generation rate in Pakistan is 0.43kg/capita/day, out of which only 50-60% is collected. The lack of effective management options for collected waste leads to dumping of the waste in open dumps. The economic benefits of operationalizing circular economy through upcycling or recycling the recyclable and non-recyclable waste remains insignificant due to weak policies and supporting actions

Given the need to not only explore the opportunity to socially, economically and environmentally benefit from the circular economy but to also create the enabling environment for piloting this model leads us to two areas of research that this study will cover. First, the study will aim to explore waste management solutions for waste managed by formal and informal waste sectors in Pakistan's context. Secondly, the study will explore the options for creating a legislative environment for piloting the circular economy. The research aims to carry out a cost benefit analysis for the implementation of circular economy utilizing existing waste streams within the country. The objectives of the research include:

1. Determine the methodology for the economic analysis of a solid waste management based on the available data and defined indicators like operational costs, etc.
2. Gather up to date and valid information based on present day requirements of the waste management sector (e.g. waste compositions, technology costs, etc.).
3. Carry out a waste sector economic analysis to identify the advantageous practice for waste management
4. Carryout extensive literature review to suggest legislative environment to pilot circular economy in Pakistan

1.5 Significance of Research:

1.5.1 Benefits derived from waste management and circular economy:

- Recovered material after recycling of waste can be sold by developing and subsidizing a market for recycled goods. This would generate revenue for the country. Recycling a ton of paper waste could potentially recover 50% of the manufacturing water footprint and the equivalent of 17 trees (UNEP, 2022a).
- Energy recovery from waste could help solve the overall energy shortage of the country by adding significant amount into the grid and to run power plants.
- Health and overall quality of life would improve when waste is frequently collected instead of being thrown out into the open dump sites, which results in various diseases.
- A proper waste management system would present employment opportunities and offer livable wages to sanitary workers and laborers, as well as many technical experts in the field. The radiwalas, pheriwalas, collectors, scavengers, and recyclers would benefit greatly from a proper system of waste allocation and handling, thus improving their livelihood as well. The recycling sector of Brazil, US, and China alone offer wages to 12 million employees (UNEP, 2022a).
- Timely collection and a proper system in place would prevent solid waste ending up in storm and sewage drains, significantly reducing the risk of blockages and flooding, which has previously resulted in horrific accidents, especially seen in Karachi.
- Land, air, and water pollution would be significantly reduced when the waste is properly disposed into landfills or incinerated. It would also prevent the leaching of

toxic chemicals into groundwater and croplands. Notable reduction would be observed in the emissions of GHGs, which would also reduce the footprint of the country.

All of the above listed benefits should be thoroughly considered during the CBA to make an informed decision regarding the importance of a proper SWM system. To allow for relevant public and private stakeholders to tap the potential socio-economic and environmental sustainability opportunities offered by circular economy, government needs to adopt legislative environment that allows for circular economy businesses to compete and flourish. The following research identifies the entry points for government to create an enabling environment that allows for the transition towards circular economy.

1.6 Organization of Thesis

Following introduction, the thesis includes four chapters. Chapter 2 extensively covers the liteartre review of different case studies from around the world on circular economy, legislative environment and economic analysis. Chapter 3 defines the methodology followed for the analysis and data collection methods. Chapter 4 covers the findings of the analysis and discusses the elements of creating enabling environment for the adoption of circular economy. Lastly, chapter 5 summarises the study findings and describes way forward.

Chapter 2 Review of Literature

2.1 Global Waste Management Statistics:

2.1.1 East Asia/Pacific region:

The World Bank's "What a Waste 2.0" report shows that 23% of the total global waste produced, was in the East Asia and Pacific region in 2016. As this region is mainly underdeveloped, it's contribution to the waste pool was quite high due to the lack of proper waste collection and processing systems. (World Bank, What a Waste: An Updated Look into the Future of Solid Waste Management, 2018).

However, in China, carbon-rich compounds are utilized in the energy and transport sector to reduce its overall carbon footprint. The government has shifted its focus towards creating zero waste cities by integrating the concept of a circular economy instead of a linear one. China's main goals are to reduce its overall fossil fuel consumption, evaluate the amount of carbon raw material utilized in various processes and find alternatives, and to recycle the inevitably used materials through mechanical and chemical processing to get the most out of the primary and secondary resources (Lee, 2020). An $80 million loan from the World Bank has enabled the country to implement anaerobic digestion facilities to recover energy from organic wastes (World Bank, Solid Waste Management, 2022).

Another positive example is Indonesia, which has improved its local waste management policies and industry after procuring a loan worth $100 million, issued by the World Bank. It has managed to close unsustainable dumpsites and allocate new sanitary landfills for waste disposal. Vietnam and the Philippines have also been able to prevent flooding due to clogged drains after channeling investments into their SWM systems (World Bank, Solid Waste Management, 2022).

2.1.2 Latin America and Caribbean region:

Latin America and Caribbean houses beyond 600 million people and MWS generation stands at 1.09 kg/capita/day where waste collection is 89.9% (Hettiarachchi, (2018)). Loans issued to various countries such as Argentina, Sint Maarten, and Jamaica have improved the overall waste management system in these countries. The primary focus, in the Latin America and Caribbean region, has been on switching away from outmoded practices regarding organic and inorganic waste. The enforcement of a newer sustainable SWM system has also created a job market and improved food security and the overall health of the countries in this region (World Bank, Solid Waste Management, 2022).

2.1.3 Africa:

African region generated 125 million tonnes in 2012 and it was projected that this figure will reach double its quantity by 2025 (UNEP, Africa waste Management Outlook, 2018). To respond to the crisis, Africa Union developed a vision that "African cities will be recycling at least 50 per cent of the waste they generate by 2023". The response by African nations concentrated on waste minimization and harnessing waste as a resource (UNEP, Africa waste Management Outlook, 2018).

Morocco has seen an increase in its fee collection rates as well as an improvement of waste management facilities and processes after being issued a $500 million loan, offering employment opportunities to 20,000 workers. Three new sanitary landfill sites have been constructed in the West Bank and one in Liberia, effectively shutting down primitive dump sites and improving sanitation for over 2 million residents. Burkina Faso has seen an upgrade in the waste and sanitation department owing to $67 million in loans. Along with two sanitary landfills, the waste sector has seen an overall improvement and a shift towards modern techniques of collection and processing of waste. 78% of the waste generated in Ouagdougou is being collected as a result of better funding opportunities (World Bank, Solid Waste Management, 2022).

2.1.4 Europe:

Most European countries have very efficient waste management systems in place, owing to surplus budget allocations and technological advancements. Germany has been actively working on implementing a waste management system since the early '90s to improve its resource utilization. As of 2018, 67% of the household waste in Germany is recycled, alongside 70% of the commercial and production waste, and 90% of construction and demolition waste. These statistics are proof of the high-functioning systems in place in Germany, which exceeds the standards for waste recovery and recycling set by the EU (Federal Ministry for the Environment Nature Conservation and Nuclear Safety, 2018). Figure 2.1 shows the steady decline in waste generation after the implementation of a circular system which encouraged reduction and recycling.

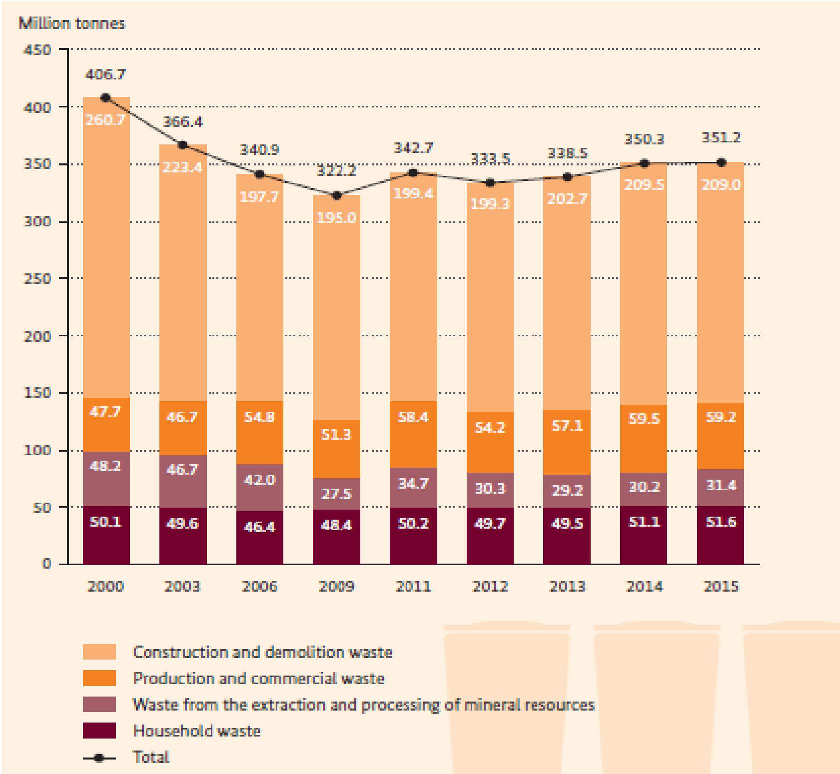

Figure 2.1 Waste Generation in Germany (2000-2015)

Source: **(Nelles, 2016) (German Federal Statistical Office, 2016)**

Additionally, Belarus and Bosnia, have both benefitted from procuring loans from the World Bank and pouring the funds into a sustainable waste management system. Their main focus has been on developing landfills and constructing a sanitary disposal system, as well as shutting down outdated dumping procedures and sites and improving the accessibility of 66% of the population to a proper SWM system (World Bank, 2022).

2.1.5 Australia:

Autralia waste generation rate is one of the highest in the world at 2.7 tons per capita per year where Australia sent most of its waste overseas (Joe Pickin, 2018). After a ban on list of solid waste types by China in 2018, the country launched its National Waste Policy to boost local recycling. The Australian government has shifted its focus towards the implementation of a circular economy by outlining important policy points such as reducing the use of products that may end up in landfills, improving the procedure of resource recovery from materials used, focusing on recycling waste as well as building a market for recycled or upcycled products, managing the flow of materials and reducing the production footprints, spreading awareness among the community to encourage waste reduction, and an overall reduction of plastic usage in the everyday lives of the people (Government of Australia, 2019).

2.1.6 South Asia:

2.1.6.1 Nepal:

The average per capita waste generation in Nepal is at 0.223 kg/person/day or 3023 tons per day which constitutes 60% of decomposable and 25% of recyclables (Pathak, 2017). The average collection efficiency of municipalities is estimated to be around 62%. Nepal is one of the asian countries to have a dedicated solid waste management National policy released in 1996 followed by a number of policies and acts dealing with SWM and sanitation like Environment Protection Rules (1997), Mountaineering Expedition Rules 2002, Solid Waste Management Act 2011,Public Health Service Act 2018, etc. (WB, 2021). The launch of a results-based project has improved the lives of 0.8 million people in Nepal through improved sanitation and waste management. An increased willingness of the common people to pay municipal waste management fee has also been observed (World Bank, 2022).

2.1.6.2 India:

Due to a growing population size and industrialization, India faces significant roadblocks in the solid waste management (SWM) process. Waste to energy conversion is carried out on small scales, but the residual material is dumped instead of it being properly disposed off in a landfill, causing many problems for the country. With the generation of 133K tons of waste per day, barely 20% of it is treated due to lack of a proper system as well as environmental engineers to run the operation. Despite having set rules and guidelines issued by the Ministry of Environment and Forests (MoEF), there is little to no implementation, causing many social, environmental, and economic issues as a result (Kumar, 2017).

2.1.6.3 Pakistan:

Being a developing country, Pakistan generates around 49.6 mil tons of solid waste yearly, and this number will keep on increasing as the country progresses. Despite the excessive amount of waste produced, the country lacks a proper waste management system, and heavily relies on dumping or combustion. Improper disposal leads to pollution, health issues, and environmental damage (ITA, 2022). The MSW of Pakistan is represented using the pie chart below in Figure 2.2.

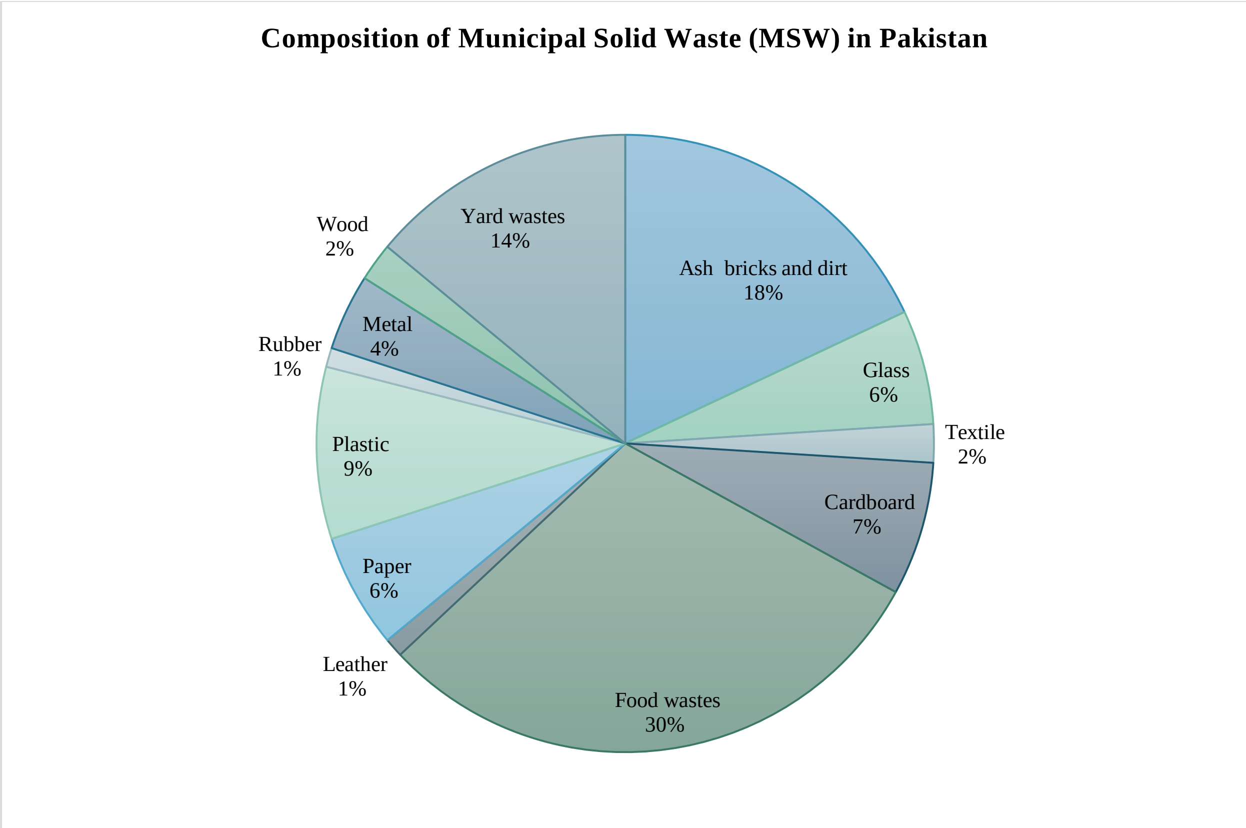

Figure 2.2 Municipal solid waste in Pakistan: Composition 2018

Source: United Nations Environment Programme, report on waste management in Pakistan

Many issues pertaining to waste management have been identified in Pakistan, including i) bureaucracy, ii) lack of public awareness and inappropriate behaviours, iii) scanty urban planning, and iv) substandard equipment. Although around 70% of waste is collected from the cities, the collection system is outdated and relies heavily on cheap labor and manual collection. In addition, even the largest metropolitan cities like Karachi and Lahore have only a few sanitary landfills with appropriate technology for safe deposit of waste, leading most cities to dump their wastes on the outskirts. Lahore has a more systemized waste management system, owing to outsourcing to Turkish companies. The Asian Development Bank (ADB) has issued funding for the introduction of a better system in the Sindh province. The Water and Sanitation Services Peshawar (WSSP) is working on designating sanitary landfills in the Khyber Pakhtunkhwa (KP) province, while Balochistan is yet to be developed in this department. Most remote and rural areas do not have a running system of waste collection, which results in pile ups, spread of disease, water and soil contamination, blockage of drainage systems, and aesthetic nuisances. Even the metropolitan areas become flooded due to waste blocking the drains resulting in health and electrocution hazards (ITA, 2022).

Despite a more systemized waste management system in Lahore, The Lahore Waste Management Company (LWMC) has been slacking on waste collection in the city, which has resulted in heaps of garbage resting in temporary dump sites, which are supposed to be cleared daily. The ineffectiveness to provide adequate sanitary services by these departments has led to prevalent unhygienic conditions and has resulted in the widespread of diseases (Khan A. F., 2021) (Khan I. U., 2019). The government procured a loan of $5.5 million from the World Bank to set up a composting facility in Lahore which has reduced emissions equivalent to 150K tons of carbon dioxide and also improved organic waste processing (World Bank, 2022).

On the other hand, Karachi being the largest city in Pakistan and also the economic hub generates the greatest amount of waste, crossing 16,500 tons daily (ITA, 2022). The departments responsible for waste management and collection are the Sindh Solid Waste Management Board (SSWMB) and the District Municipal Committee (DMC) which carry out front-end collection from various communities and transport them to temporary dump sites where sorting is carried out. Not only does Karachi suffer from a compromised and inefficient waste management system, but also from the negligence shown by provincial departments in calculating the daily waste output of the city. Such miscalculations made by policy makers and the administration have led to exacerbated management and processing problems related to waste, resulting in the piling up of wastes, and in turn the clogging up of drains and consequently flooding, as well as the spread of various diseases (Imran, Karachi – where garbage is piling up., 2019).

The informal sector is also heavily concentrated within the waste sector of Pakistan serving the intermediary role of collectors and scavengers but very inconsistently. National Living Standard Surveys show the collection of waste by government municipalities to be only 17%, revealing poor practices and low coverage. 39% of urban areas are covered under garbage collection while only 2% of rural areas have such facilities. A national survey, the Pakistan Living Standard Measurement 2019-20 reveals that 67% of households do not have access to a functional garbage collection system (PBS, 2019-20).

Only the major cities of Pakistan are linked with a landfill site. The majority of the rest of the country either utilizes dumping sites or practices waste incineration or underground burial in undesignated areas (ITA, 2022).

2.2 Enabling Environment for Circular Economy:

Despite the social, economic and environmental needs of switching to a circular economy model, most economies today continue to function on the traditional linear economic system, despite its significant loopholes, and the overall huge carbon footprint that it is leaving behind. As Mazur-Wierzbicka (2021) explains, the linear economic system is based on the 'take-use-dispose' model, in which little to no consideration is placed on the environmental impact that the production and consumption of materials results in, making it an unsustainable model. With only a finite amount of non-renewable resources, many countries have now started realizing the threat of this model to their socio-economic progress. As an alternative to the traditional linear model, the circular economy system is based on the 'take-use-reuse' model (Mazur-Wierzbicka, 2021). The circular economy is a cyclic model in which resources are efficiently used and re-utilized, to get the most out of them, and to prevent any kind of waste, or at least minimize it. This model adds value to raw materials and products to encourage a zero waste closed loop. This not only benefits the environment through reduction of footprint, but also has many socio-economic benefits for the country implementing it. Adopting the 4 R's (reduce, reuse, recycle, and remove) ensures significant reduction in greenhouse gas emissions and the global carbon footprint. In addition to the 4 R's, there are many other strategies that can be employed to reduce waste, such as repurposing, repairing, refusing and rethinking, and utilizing existing products as starting material, under the circular economy model (Morseletto, 2020).

However, achieving a circular economy is a complex process that requires systematic changes in various areas such as - legislation, urban planning, businesses and corporate models, product design and services, materials extraction, their processing, and their transport - all of which need to be reoriented from a circular economy perspective. Quality infrastructure that will support and maintain a circular economy also needs to be developed. Thus, costly initial investments need to be made in order to achieve circularity in the economy. This perhaps explains why developing countries are lagging behind in adopting a more sustainable system of resource management as compared to the developed countries. However, despite the seemingly large initial investment costs, there are large opportunity costs being incurred that are going unaccounted for by mismanaged waste. Waste that is ending up in landfills to be burnt or deposited is causing health, environmental, social and economic hazards. Not only are finite resources getting depleted, but irreversible damages to the environment are being caused.

To create an enabling environment for the adoption of the circular economy model, literature suggests that the elements mentioned in figure 2.3.

Figure 2.3 Elements to create an enabling environment for Circular Economy

2.2.1 Case study on Elements to create an enabling environment for Circular Economy

The circular economy has been gaining grounds in all public and private enterprises as it aids economic growth by reducing production cost. Meanwhile, circular economy encourages innovation and creates more robust employment. The circular economy will not only benefit businesses and the economy at large, but its social implications are incredible. Ranging from increased disposable income to diversification in livelihood, healthy living is also a plus. To foster these benefits, nations have started developing institutional frameworks and strengthening legislative environment. A few examples of such approaches are highlighted below including one example from Pakistan.

2.2.1.1 National Action Plan on Sustainable Consumption and Production (NAP-SCP):

In recent years, Pakistan has taken steps towards a more sustainable approach of development. Pakistan, in accordance with the sustainable development goals SDGs and vision 2025 (Ministry of Planning Development & Reforms, 2019), developed an action plan on SDG 12 sustainable consumption and production in 2017 namely, National Action Plan on Sustainable Consumption and Production (NAP-SCP) (Ministry of Climate Change, 2017). This has been first effort at national level since the 18th amendment to support the provinces through a guideline document to mainstream the concepts of sustainable consumption and production. This serves as a strong policy document to support the systematic shift from linear to circular economy model. The action plan covers short, medium and long-term actions that provincial departments can contextualize to their local systems. On the subject of creating an enabling environment for the successful implementation of the plan, the following actions are listed in figure 2.4.

On the financial measures, the action plan covers number of fiscal measures for the adoption of sustainable consumption and production behaviours like tax rebates on energy efficient appliances, tax incentives for independent power producers to shift to clean energy, etc. Similarly, to support public-private partnerships, the action plan includes provisions like introducing investment-friendly incentives, etc. For financing the action plan, the plan includes measures to tap international finance.

Legislative and regulatory steps including timeline

- Mainstream SCP in national sectoral policies, strategies and planning.
- Integration of policy guidelines on Green Building Codes into National Building Code of Pakistan.
- Prepare guidelines for segregation, environmentally safe management and disposal of municipal, industrial, hazardous & biomedical waste.

Capacity for sustainable governance

- Design and implement projects to provide environmentally sound alternatives for phasing out plastic bags
- Design waste to energy projects to promote environmentally sound disposal of waste as well as their utilization to overcome energy crisis.
- Launch programmes and projects for minimization of food waste.

Awareness raising and communication/ Science, Technology, and Innovation

- Launch awareness programmes for dissemination of SCP principle at primary, secondary and tertiary education level. Conduct Summer/Winter School Programmes in collaboration with UN Environment at national & provincial levels.
- Designing of coarse material for teaching SCP in the priority subjects identified by the SCP pilot on tertiary level curriculum.
- Integrate SCP in vocational training and distant learning programmes.

Figure 2.4 NAP-SCP Provisions

Source: (Ministry of Climate Change, 2017)

Later, in year 2021, a monitoring framework for NAP-SCP was also developed to record the implementation of the action plan and report the progress. This allows for building local capacities to gather and compile the data on set of indicators defined and use this information to inform future decisions e.g. for budget allocations, proposing new projects, mobilizing international finance, etc.

These set of policy directions are a great example of how a circular economy model can be supported through a similar action plan at national level that allows provinces to benefit from a guideline or a tool to adopt similar action plan while creating local capacities and awareness on the said topic.

2.2.1.2 European Union's Circular Economy Action Plan

The European Commission adopted the new Circular Economy Action Plan (CEAP) in March 2020 under European Green Deal; CEAP provides a future-oriented agenda for achieving a cleaner and more competitive Europe in co-creation with economic actors, consumers, citizens and civil society organizations (EU, 2020). The transition towards a circular economy is already underway, with frontrunner businesses, consumers and public authorities in Europe embracing this sustainable model. This plan makes sure that the circular economy transition delivers opportunities for all, leaving no one behind.

More specifically, CEAP details measures to make sustainable products the norm in the EU ensuring less waste, empower consumers and public buyers, focus on the sectors that use most resources and where the potential for circularity is high such as: electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, food, water and nutrients. It introduces legislative and non-legislative measures and target areas where action at the EU level brings added value (EU, 2020).

A few comprehensive set of actions under the plan are as follows:

Legislative and regulatory measures

- Legislative proposal for substantiating green claims made by companies - reducing 'Green washing' (companies giving a false impression of their environmental impact).
- Review of requirements on packaging and packaging waste in the EU (reuse & recycle).
- New policy framework on bio-based, biodegradable and compostable plastics.
- Measures to reduce the impact of micro plastic pollution on the environment (focus on labeling, standardization, certification and regulatory measures).

Capacity for sustainable governance

- Sustainable Products Initiative, including the proposal for the Eco design for Sustainable Products Regulation.
- EU strategy for sustainable and circular textiles
- Proposal for a revised Construction products Regulation
- Proposal for empowering consumers in the green transition

Awareness raising and communication/ Science, Technology, and Innovation

- Promoting the use of digital technologies for tracking, tracing and mapping of resources.
- Supporting the sustainable and circular bio-based sector through the implementation of the Bio-economy Action Plan.
- Global Alliance on Circular Economy and Resource Efficiency (GACERE) - identifying knowledge and governance gaps in advancing a global circular economy.
- Focus on electronics and ICT as a priority sector for implementing the 'right to repair', including a right to update obsolete software.

Figure 2.5 Provisions under EU Circular Economy Action Plan

Source: (European Commission, 2020)

Accelerating the green transition requires careful yet decisive measures to steer financing. CEAP's fiscal directives include; integrating the circular economy objective under the EU Taxonomy Regulation, and carrying out preparatory work on EU Eco label criteria for financial products. Financial instruments, such as SME guarantees under the current framework and InvestEU as of 2021, mobilize private financing in support of the circular economy. Therefore, the transition to the circular economy will be systemic, deep and transformative, in the EU and beyond.

2.2.1.3 Victoria's Plan for Circular Economy

Recycling Victoria: A new economy, steps out the systemic change that is needed to cut waste and boost recycling and reuse of precious resources (State of Victoria Department of Environment, 2020). This is a plan for a cleaner, greener Victoria with less waste and pollution, more jobs and a sustainable and thriving circular economy. It rests on the strategy of 3Rs (Reduce, Reuse & Recycle).

The action plan comprises of following:

Figure 2.6 Provisions under Victoria's Plan for Circular Economy

Source: **(Victoria Government, 2021) (Government) (State of Victoria Department of Environment, 2020)**.

The fiscal policy of Victoria's Plan for Circular Economy revolves around the Sustainability Fund, established under the Environment Protection Act 2017, receives money collected from the landfill levies to support projects, programs, services or technologies that will benefit

Victoria environmentally, socially and economically. The Municipal and Industrial Waste Levy (MIWL) is introduced to encourage recycling by putting a price on every ton of waste that goes to landfill. In addition, to inform future course of action, Victorian waste education strategy is put in place to review priorities and direction.

2.2. Conceptual Framework for Economic Analysis:

The global average waste exceeds 11 billion tons per year, with electronic waste being at the forefront. The toxic compounds present in electronics pose a serious health threat for the developed, and developing countries alike. The International Environmental Technology Center (IETC) of the United Nations Environment Program (UNEP), currently functioning in Japan, is a pioneer in curtailing the issue of waste management by applying an integrated approach for waste management, particularly in developing countries (UNEP., 2022). The World Bank's "What a Waste 2.0" report, disclosed that 90% of marine pollution is a result of plastic waste dumping. In 2016 alone, 242 million tons of plastic waste was generated globally (World Bank, 2018).

Moreover, the open dumping of solid waste has been observed to be a major contributor towards rising greenhouse gas emissions, which is an another pressing environmental concern globally (World Bank, What a Waste: An Updated Look into the Future of Solid Waste Management., 2018). Other unsustainable waste management practices have also lead to a whole host of social and environmental issues, such as the spread of various diseases, unsanitary living conditions, drinking water contamination, and climate change acceleration - just to name a few. Statistics suggest that 2.01 billion tons of waste, equals to an environmental footprint of 0.74kg/day per individual (World Bank, 2022).

Thus, an all-inclusive waste management system, which will cater to the majority of the economic, social, and environmental demands, is the need of the hour. In light of this, the World Bank has introduced various loan programs and advisory services through life cycle analysis, (from the generation of waste to the continuous cycle of collection, transportation, treatment, recycling, and reduction), which should be effectively utilized globally, to improve the current waste management practices. Developing countries, in particular, need to be incentivized to make use of such loans and advisory services, as their budget constraints pose as a barrier towards progress in the right direction.

2.2.2 Circular Economy and Life Cycle Assessment (LCA)

However, while the circular economy model seems like the obvious alternative to the current traditional linear model implemented in many countries, it's feasible implementation remains a task that needs to be understood and then monitored closely. A tool that is able to evaluate the impacts of the circular economy at every stage needs to be employed, in order to effectively transition to a circular economy. The Life Cycle Analysis approach is one such tool. The LCA takes into consideration the entire production footprint of a certain product that may end up in a landfill, from its raw form to the final product. Under the LCA scope, the direct and indirect impacts are studied, which include emissions, water consumption, raw materials and their source, as well as the operational costs for manufacturing (Consonni, 2005).

The UN Environment Department introduced the Life Cycle Initiative which involved various stakeholders from the public and private sectors to incorporate the entire life cycle of waste, from production to treatment, and then disposal. In an effort to make it more accessible globally, the UN launched the 'Resource Efficiency through Application of Life Cycle Thinking' (REAL) project, which focused on data availability on the life cycle of waste products and training the policy makers in LCA to incorporate it in the decision making process (UNEP, The REAL project | UNEP - UN Environment Programme. , 2022b).

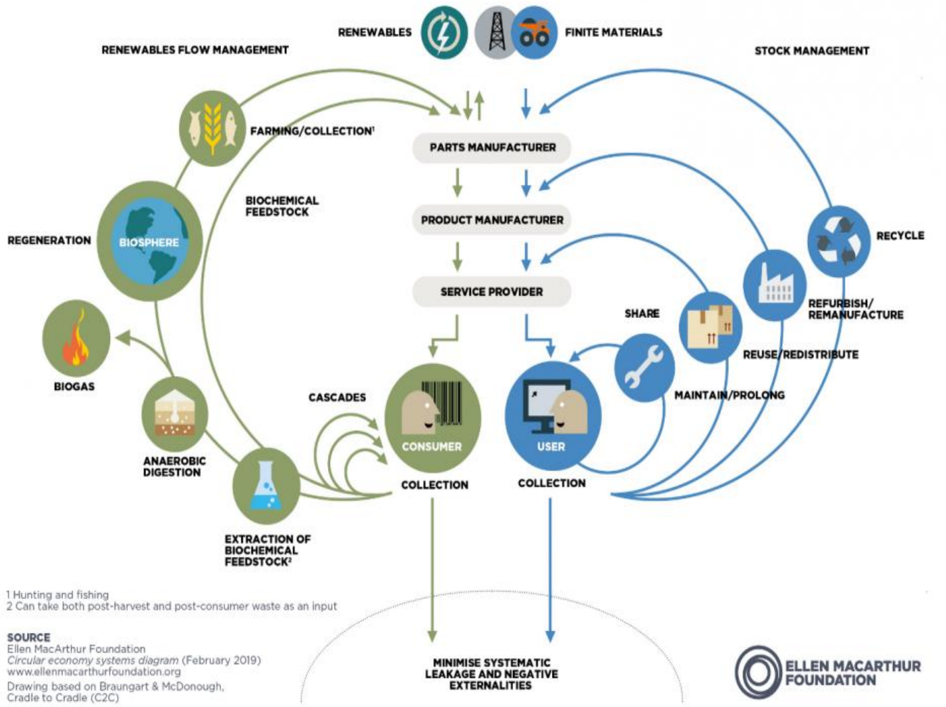

Figure 2.7 Schematic diagram of a circular carbon economy

Source: **(Ellen MacArthur Foundation, The butterfly diagram: visualising the circular economy, 2019)**

2.3 Waste to Energy potential for Pakistan in achieving circularity

While clear efforts are being made towards a more sustainable method of growth, deeply entrenched limitations within Pakistan's society are keeping it from achieving this goal. Consumerism, a primitive waste processing system, lack of public awareness, and corruption are all major factors in contributing towards an inefficient system of production and consumption, the result of which is the rise in Municipal solid waste (MSW) in Pakistan, and the associated growing environmental and health hazards brought about by its mismanagement. Table 2.1. shows a breakdown of the waste management issues of different cities in Pakistan, that continue to persist. Despite the NCP-SAP goal of segregating the waste at the source and then managing its disposal according to its category, majority of the waste in Pakistan ends up being dumped in landfills, where the piling up situation is either getting worse, or the waste that is being burnt openly, is resulting in an even more dire situation of the air pollution quality. Given this situation and the country's energy problems, a technology option that seems to offer a promising solution is Waste to Energy (WtE) technology. Thermal energy obtained from the WtE pipeline has been the market leader in most developed countries in Europe, as well as Japan where 60% of the waste is incinerated.

Table 2.1: Major challenges regarding solid waste management in major cities of Pakistan

City	***Municipal Solid Waste Per Day***	***Energy Recovery Potential***	***Waste Collection Challenges***
Lahore	6,778 tons	341 MW per day	• Lengthy bureaucratic processes • personnel shortages • Lower calorific value of waste • Lack of machinery • Ghost employees • Lack of planning
Karachi (Jam Chakro)	9440 tons	121.9 MW per day	• Bureaucratic hurdles, • Lack of planning • Inadequate waste management equipment • Low public awareness
Rawalpindi	1,280 tons	49 MW per day	• Shortage of machinery, dumping infrastructure • Lower calorific value of waste
Faisalabad	4883 tons	NA	• Negligence of Punjab Government and sanitation departments • Using primitive methods • Lack of funds • Lack of infrastructure
Peshawar	1888 tons	NA	• Lack of proper funding • Primitive infrastructure • No proper collection system

Quetta	326 tons	NA	• Negligence • Lack of proper infrastructure and planning • Monetary constraints

Source: (PBIT, 2018)

There are various methods that can be applied for WtE conversion, such as:

i. Gasification

ii. Anaerobic digestion

iii. Plasma incineration

iv. Incineration

Under these technologies, waste is burnt directly in an incinerator or converted to syngas through gasification to produce heat. The heat energy is then used to drive power plants for energy production. Waste to energy (WtE) technology utilizes waste which would otherwise end up in a landfill and converts it into clean energy. It also removes dioxins and carbon monoxide from the waste which would otherwise worsen air quality. Statistics show that 600kWh electricity can be generated utilizing one metric ton of solid waste through the WtE method.

In Pakistan's city, Lahore, efforts to implement a WtE Pipeline on the oldest dumping site, the Mehmood Booti site, have started (LWMC, 2022). The site covers an area of 40 acres and was closed for dumping after reaching its capacity in 2016. The WtE Pipeline being set up there, is to produce combustible natural gas, whose output will be 1 cubic meter of methane/day and it would maintain a steady supply for the next 7-10 years. As methane has a higher global warming potential compared to carbon dioxide, this project is a sustainable solution towards many environmental problems and will save Pakistan 7 tons in carbon credits (LWMC, 2022). LWMC's waste management and disposal techniques are highlighted in Figure 2.8.

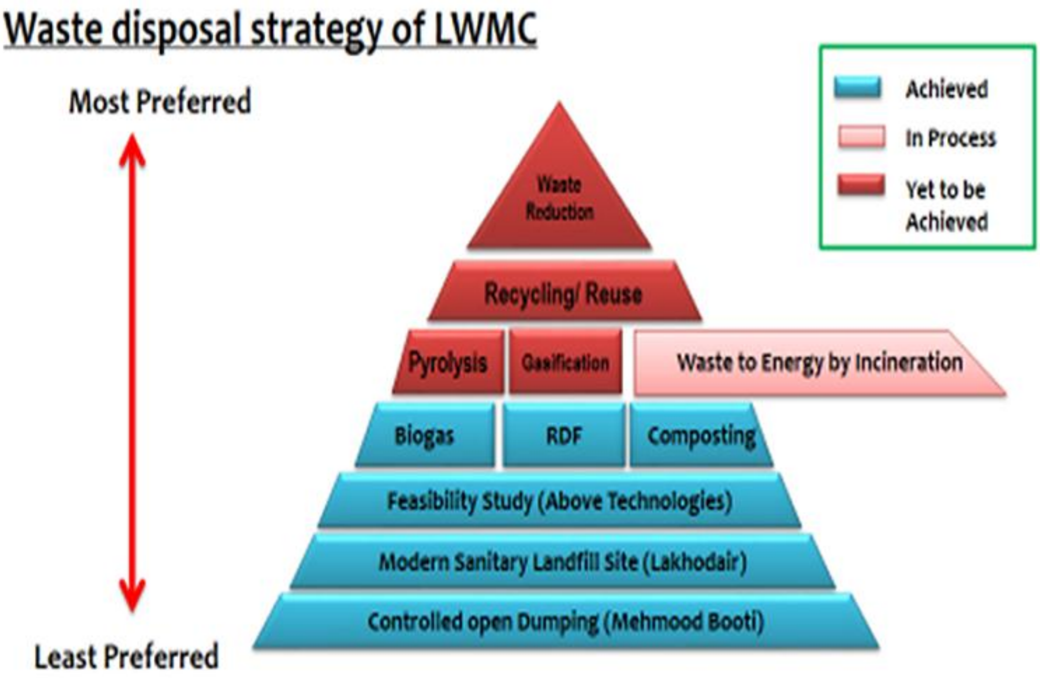

Figure 2.8 LWMC's waste disposal strategy

Source: (LWMC, 2022)

In Karachi, out of the three landfill sites located there, Jam Chakro and Gond Pass house waste with a greater calorific value which can be converted to energy sustainably. Statistics show that 8000 tons of solid waste obtained from the Jam Chakro landfill could be converted to 121.0MW of electricity, which could be added to the energy mix of the city (Siddiqi, 2019b). Additionally, a 250MW power generation project based on the WtE pipeline has been initiated by the National Electric Power Regulatory Authority (NEPRA) assigning a U.S. cents 10/kWh tariff to supply 50MW each, to all provinces and the Federal territory (ITA, 2022) (DAWN, 2018).

Table 2.2. outlines various parameters that can be utilized during the selection of a suitable WtE treatment technology which can be applied to a particular type of waste.

Table 2.2: MSW parameters considerable for WtE treatment technologies

Parameters	Biochemical treatments	Thermochemical treatments

Suitable waste fractions	Biogenic waste	Wood, paper, packing boxes, grass trimmings, textiles, rags, nylon, poly-sac, plastic bottles, food residue
Moisture content	>50%	<45%
Volatile matter	>40%	>40%
Carbon to Nitrogen(C/N) ratio	25–30%	–
Fixed carbon	–	<15%
Ash content	–	<35%
Net Calorific Value(NCV)	–	>2400 kcal/kg or 10.0416 MJ/kg (incinerated autogenously)
Low Heating Value(LHV)	–	21 MJ/kg
Elements		High sulfur and carbon

Source: (Siddiqi, 2019b)

However, although the impacts of Wte technologies seem promising both for the waste management and energy supply issue in Pakistan, its implementation requires a thorough analysis. Switching from landfill management to Wte technology can be very costly and not possible if certain conditions are present. For example, Wte technology is suited to process waste that is high in it’s moisture and biodegradable content.Food and yard waste, as Agaton et al., (2020), highlight are most effectively processed by anaerobic digestion which involves a ‘complex process requiring specific environmental conditions and different bacterial populations to decompose the organic waste to produce a valuable high energy mixture of biogas’ (Agaton, 2020). Therefore, there are many considerations which need to be made when deciding the most optimal waste management solutions for different cities. It is also important that costly solutions are not written off simply due to financial constraints, as the opportunity costs from not implementing them may be higher in the future. Thus, sustainability assessment tools that are able to evaluate the impacts of SWM treatments and the transition towards a circular economy, such as Cost-Benefit Analysis (CBA), Life Cycle Analysis (LCA) and Life Cycle Costing (LCC), Returns on Investment (ROI), Internal rate of return (IRR), multi-step approach, to name a few, need to be increasingly utilized for project evaluations. It is important that SWM projects being implemented are financially, economically and environmentally viable (Hoogmartens, 2014) (Agaton, 2020).

2.4 Waste Management Case Studies from Various Countries:

A literature review has been conducted, reviewing searches for the various types of waste management systems that have been implemented in different countries to determine the best suited method for Pakistan. These case studies offer insights into the applications of a well-designed SWM system, as well as the statistics of the cost-benefit analyses conducted after the implementation of the system. Short summaries of the methods and the results obtained have been included within this document to make a more informed decision in the context of Pakistan.

2.4.1 Barcelona, Spain:

This paper provides a comprehensive methodology for the technical-economic assessment of waste management technologies. Medina-Mijangos et al., (2021) highlight how it is important to analyse the external impacts along with the internal impacts of implementing a SWM system (Medina-Mijangos, 2021). The external impact includes the environmental and social impacts. Not only does this framework analyse whether a specific waste management technology yields private benefits and is thus, financially viable, but also that it is socially, environmentally and economically feasible too. The risk and uncertainty of implementing a certain system through this analysis is reduced. Medina-Mijangos et al., (2021), applied their methodology to a case study of a light packaging and bulky waste facility in Spain. Through this analysis, they evaluated the private benefit of the stakeholders to be at 42.94 €/ton and the total benefit (social, environmental, economic, and financial) to be calculated at 87.73 €/ton.

Table 2.3: **Variables of the case study from Barcelona, Spain**

Independent variable	**Dependent variable(s)**	**Private Benefit (€/ton)**	**Total Benefit (€/ton)**	**Opportunity Cost (€/ton)**	**Equation**
Opportunity cost	Cost of Energy	42.94	87.73	89.5	$B_T = B_P + B_E - OC$ * B_T= total benefit B_P = Private benefit B_E= External benefit OC= Opportunity cost
	Utilized capacity of treatment facility				
	Processing and treatment fee				
	Revenue generated from selling recycled waste				

2.4.2 Tehran-Iran:

Hosseinalizadeh et al., (2021) conducted a technical-economic study in Tehran, Iran and applied two different scenarios for waste management (Hosseinalizadeh, 2021). They defined solid waste to contain glass, metals, organic waste, plastics, paper, dry waste, and other types of waste materials. The 7 waste treatment processes to be applied in the scenarios were anaerobic digestion, composting, incineration, landfill with and without gas recovery, gasification, and recycling. An augmented ε-constraint method was used to carry out the analysis, and integrated all seven processes in the first scenario, while excluded composting and recycling in the second one due to lack of proper infrastructure for these treatments.

Objectives set for evaluation in the model are Income, air pollution, and the volume of treated waste. The most efficient energy production method in the first scenario was determined to be recycling, composting, and gasification in terms of cost and income, gasification and incineration in terms of air quality, and incineration in terms of volume of waste treated. In terms of income, gasification, anaerobic digestion, and landfills are suggested, while gasification, incineration, anaerobic digestion, and landfilling are the suggested treatments in terms of air quality and waste volume. Table 2.4 outlines the results for the various scenarios in terms of the objective functions selected. A negative income value shows that the revenue generated from the scenario is higher than the expenditure. Amount of waste generated daily per person is 700g. The overall average capacity for gasification is 10426kW and 30827kW in the first and second scenarios, respectively, while for incineration, 31777kW capacity was deduced in the first scenario, and 62437 kW for the second scenario, making it the dominant and preferred treatment method.

Table 2.4: Variables and results of case study from Tehran, Iran

Scenario applied	**Objective function**	**Income (dollars)**	**Air quality**	**Volume of waste disposed (tons)**	**Equation**
First Scenario	Cost	3.5 × 108	9.7×10^6 kg CO_2eq	6×10^6	$Cost = \sum_{Tech} Expenses_{Tech} - Incomes$
	Air pollution	-3.1 × 108	3.2×10^6 kg CO_2eq	5.9×10^6	
	Volume	-2.35×10^8	9.7×10^6 kg CO_2eq	5.3×10^6	
Second Scenario	Cost	-5.35×10^7	2.5×10^7 kg CO_2eq	5.86×10^7	
	Air pollution	2.45×10^7	5.6×10^6 kg CO_2eq	5.86×10^7	

	Volume	1.79×10^8	2.5×10^7 kg CO_2eq	5.71×10^7	

2.4.3 Nigeria:

The waste collected every day in Nigeria's capital city, Abuja, is around 442.83 tons. Recycling and reuse of waste was determined to be the most prominent and sustainable waste management approach by Barma M., & Modibbo, (2022) in their study through application of a mathematical model. Many model parameters were applied, such as the amount of waste collection, the operational costs for treatment, capacity of treatment plants, transportation costs, and others (Barma, 2022). Daily budget allocated for waste collection, processing, recovery, and disposal was 12,097.16 USD, out of which 9,169.41 USD was utilized to completely transport the waste for disposal. The study found that at 71.5% waste recovery, zero amount of budget would be required for waste collection and disposal, as the recovered material would compensate for the expenditure.

2.4.4 Brazil:

More than 6500 tons of solid waste is produced in Brazil, yet there is no proper arrangements for the processing or treatment. Three suggested treatments are to be applied on the collected waste from 19 municipalities of Brazil, which are anaerobic digestion, home composting, and community comporting. Three different scenarios have been applied for the economic analysis of the waste processing schemes applied, where pessimistic, moderate, and optimistic scenarios have shown varying results and revenue statistics. Startup cost for the 20 year SWM project have been determined to reach 8,951 million R$ in the optimistic scenario, where the collection and transport sector require the highest level of funding from the allocated budget. Setting up incinerators and constructing landfills at the central point could help alleviate some of the transport costs (Colvero, 2014)

Table 2.5: Investment and operation costs for waste management techniques in Brazil

Facility type	Suggested costs ($R\$.t^{1}$)	
	Initial investment	Operating costs

Waste collection – Reichert (2013):		-	269.25
Source-separated collection of recyclable waste		-	247.47
Source-separated collection of biowaste		-	131.39
Commingled waste collection (mixed waste)			
Materials Recovery Facility – BNDES (2014):			
Less than	10,000 inhabitants	47.39	689.30
Between	10,000 and 30,000 inhabitants	23.69	653.39
Between	30,000 and 250,000 inhabitants	25.85	710.84
Between	250,000 and 1,000,000 inhabitants	16.51	172.32
More than	1,000,000 inhabitants	10.05	100.52
Transfer station – Pereira et al. (2013)		6.10	28.98
Home composting – EC (2000)		238.14	1.02
Tsilemou and Panagiotakopoulos (2006):			
Windrow composting		$y = 4,000\ x^{0.7}$	$y = 7,000\ x^{-0.6}$
Anaerobic digestion		$y = 35,000\ x^{0.6}$	$y = 17,000\ x^{-0.6}$
Incineration		$y = 5,000\ x^{0.8}$	$y = 700\ x^{-0.3}$
Large landfill		$y = 3,500\ x^{0.7}$	$y = 150\ x^{-0.3}$

2.4.5 Philippines:

Agaton et al., (2020) studied the waste to energy potential in Philippines, mainly based on thermal treatment options such as incineration, gasification, and pyrolysis (Agaton, 2020). They applied an ROA methodology to determine the feasibility of applying various WtE projects in the country. Results showed that incineration and other WtE projects showed higher profitability rates than landfilling and dumping of wastes. Incineration of waste proved to be the best investment for a developing country with a limited budget for waste management, followed by pyrolysis and gasification. The statistics obtained after applying the ROA analysis model show that incineration has the highest success rate, with the generation of electricity at USD 3cents/KWh, compared to USD 7cents/KWh from gasification, and USD 12cents/KWh from pyrolysis, whereas the current cost of electricity in the country is USD 11cents/KWh. The study suggests shifting from landfilling to more sustainable technologies that incorporate the WtE pipeline. This shift could recover energy from the excessive amounts of waste and also generate revenues for the country. The variables incorporated in the study as well as the fluctuation in electricity prices resulting from sensitivity analysis of each variable are presented in Table 2.6.

Table 2.6: Variations in electricity prices based on sensitivity analysis

Variables	Pyrolysis	Gasification	Incineration
Tipping Fee	−0.32	−0.46	−1.33
Volatility of Electricity Prices	0.16	0.31	0.67
Growth Rate of Electricity Prices	−0.72	−1.08	−0.33
Discount Rate	1.44	1.15	0.33
Investment Cost	1.20	0.77	3.33
Operational Cost	1.60	3.08	6.67

Plant Capacity	−0.04	−0.08	−0.08

Source: Agaton et al., (2020)

2.5 Conclusion

After thoroughly reviewing these case studies, it can be deduced that each country and region have a specific climate, resources, public attitudes, existing infrastructure, and availability of funds, and all of these factors can influence the method of SWM applied in real time. By utilizing these statistics as well as conducting a CBA, the best method in the context of Pakistan, can be determined in terms of implementation, feasibility, efficiency, and profits. Being a data poor country has always been a challenge for Pakistan to make informed decisions and planning for management of waste requires statistics that are not novel but the capacity to collect and maintain that data is limited in Pakistan. Therefore, the methodology adopted and analysis performed for Pakistan will depend on data available for Pakistan.

Chapter 3 Data and Methodology

Switching to a circular economy model of material usage and waste management is in Pakistan's best interest, as it will help minimize waste and significantly reduce its cost of collection, treatment, and disposal. This section aims at determining a methodology to test for any viable waste management options, available in the country, that help reduce waste, given the available data. This section also discusses the collection of waste composition data and waste management data, available against two cities (Bahawalpur and Gujranwala) to make generalizations for the country.

3.1 Research strategy:

The main ethical considerations underlying this waste research are: our duty to protect the environment, uphold the law, uphold high expectations from waste managers and carriers while simultaneously keeping in mind community centric needs. It is imperative to remember that waste does not go away with waste management per se, landfills are sites of forgetting made possible through legislative decision-making and community accession. In the context of environmental ethics, the vulnerability of humans who are in repeated exposure to such landfill sites must be kept in mind, and knowledge building between humans and non-humans must be considered.

Through the approach of justice and sustainability, it must be kept in mind that the complete elimination of landfills is not possible; hence the focus must not solely be on waste management technologies. Rather, the impact of improper waste management from a community-centric point of view must be kept into consideration, and social responsibility must be a core ethical tenet of this research. The people most impacted include the formal and informal sector of waste managers, which often include people from marginalized backgrounds who are often exposed to waste not just as a means to survive but as an active biohazard that diminishes their quality of life. Waste management must include both the formal and informal sector of the economy and informal stakeholders should also be a larger part of the discussion around waste management (Nawaz M. M., 2021)

Building on these viewpoints, the circular economy research requires diversity and inclusivity at the same time. This leads us to choosing the cities from where the data availability was ensured and also the research in these areas is limited when it comes to management approaches. This research is designed to inform the potential that exists of progressing socio-economic development and environmental conservation through circular approaches.

3.1.1 Principles/Approach:

For Pakistan's case, a Cost Benefit Analysis (CBA) strategy was determined to be the most suitable methodology, in testing for the viability of different waste utilization options, given the locally available data. Through conducting a CBA, this paper aims to help decision-makers and stakeholders identify risks more clearly, and also to help them make better decisions regarding waste management in Pakistan, while keeping in consideration the limitations in funding and available resources.

To calculate the cost benefit analysis (CBA) of investment in a waste treatment option, following equation (1) will be used:

$$CBA_k = \sum_1^{T_{k+1}} \rho^t (B_k + C_k) - CAP_k = \sum_1^{T_{k+1}} \rho^t \left[\left(P_{e,t} Q_k + TF\right) + C_k\right] - CAP_k \ldots\ldots\ldots\ldots\ldots(1)$$

Where CAP_k = Investment cost for technology

T_k= lifetime of WtE technology

$\rho^t = \frac{1}{(1+\delta)^t}$ = discount factor;

δ = discount rate

B_k = revenue which equals the tipping fee (TF) and the amount of electricity generated Q_k x generation rate P_e

C_k = operational costs (maintenance, operation, taxes, salaries, and insurance)

The above equation was developed, given the availability of data. There were many other considerations that this CBA could have taken in to account, to make it a more comprehensive analysis, however, given the limitations, those parameters were not included. In an ideal scenario, costs incurred at every stage of the waste management process would have been included.

3.2 Research Design:

Three waste treatment processes were identified to be tested under the CBA developed above. These three processes include, Gasification, Incineration and Pyrolysis. The investment cost of these processes, their marginal operational and management costs per annum, the electricity generated per year statistics, the tipping/gate fee, the lifetime of the technology used in these processes, current electricity price and the discount rate set by the government were gathered. Table 3.1. provides a summary of the statistics collected.

Table 3.1 Parameters for cost-benefit analysis for SWM system

Parameter	Unit	Description	Gasification	Incineration	Pyrolysis
CAP_k	PK R million	Investment cost	3200	2352.8	5666.61
C_k	PKR million/year	Annual marginal operations and management cost	930.75	744.6	930.75
Q_k	Electricity generated/year	MWh/year	24,090	21,353	24,090
TF	PKR million/year	Tipping fee/gate fee	NA		
T_k	years	Lifetime of technology/operation	20	20	20
Other Parameters					
$P_{ecurrent}$	PKR/kwh	Current electricity price	*PKR 2-24/unit		
δ	percentage	Discount rate set by government	NA		

**Electricity rates depend on the units consumed*

Source: (Agaton, 2020) (NEPRA, 2022)

A discount rate of 13.25% which had been issued by State Bank of Pakistan in April 2022 is used for the analysis. There was no history of cashflows from which future could have been predicted. Thus, the cashflows are considered as fixed, for this paper.

3.3 Data Collection Methods:

The local government departments including Water and Sanitation Authority (WASA) and Public Health Engineering Department (PHED) were consulted to collect most recent stats on city waste (Annex 1). The data was provided based on the year 2019-2020. The data was collected against following queries covering waste generation, composition, treatment and disposal:

Item	Description	Unit
Municipal solid waste generation per capita	How much municipal solid waste per person is produced per day ?	Kg/capita/day
Municipal solid waste composition	Paper, Plastics, Glass, Metals, Organic, etc.	Weight-%
Formal and Informal service chain	How much MSW is disposed of in disposal facilities? How much MSW is sorted by the formal sector for recovery? How much MSW is sorted by the informal sector for recovery?	Tonnes per day
Managed in controlled facilities	How much of the sorting for recovery is managed in controlled facilities (excludes energy from waste)?	% of waste sorted for recovery
	How much of the waste sent for energy from waste is managed in controlled facilities?	% of waste sent for energy from waste
	How much of the waste at disposal facilities are managed in controlled facilities?	% of disposed waste

3.4 Baseline Data on Waste Management in Gujranwala and Bahawalpur

Data was successfully collected on Bahawalpur and Gujranwala's waste composition and waste cycle. Both the cities are located in the Punjab province of Pakistan (figure 3.1). Bahawalpur is 11th largest city in Pakistan while Gujranwala is 5th most populous metropolitan (Pakistan Bureau of Statistics, 2017).

Figure 3.1 Map of Punjab province, Pakistan

Source: (Janjua, 2021)

The collected data on waste composition is reflected in the flow charts below:

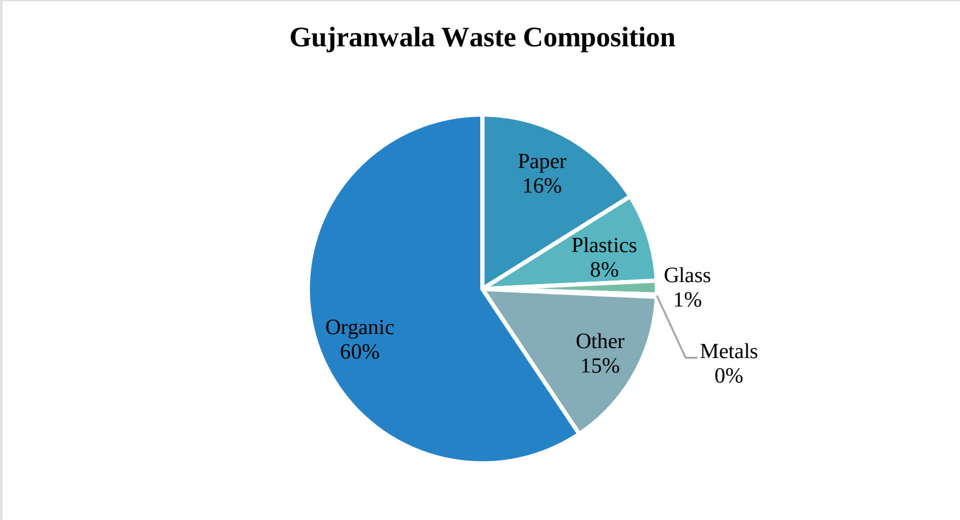

Figure 3.2 Municipal Solid Waste Composition for Gujranwala

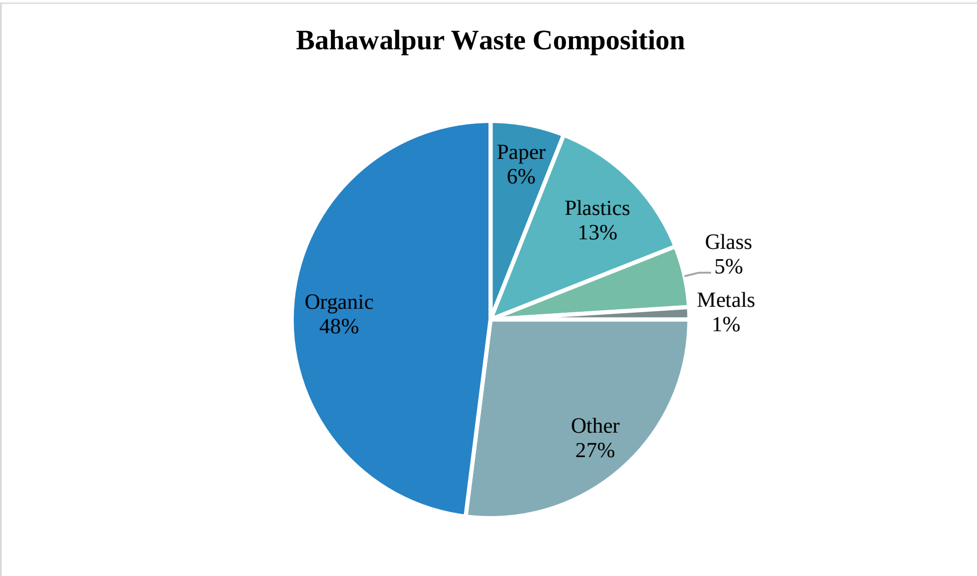

Figure 3.3 Municipal Solid Waste Composition for Bahawalpur

As the flow charts above show, organic waste constitutes the highest percentage of the waste collected; 48% of the waste collected in Bahawalpur is organic, whilst that number increases to 60% in Gujranwala. Plastics and paper were two other clearly identified categories, constituting a good proportion of the overall waste composition. There is a need for formulating policies and promoting projects like leveraging advanced information technology solutions for circular economy system for recyclables including plastics, paper, glass, metals, etc. For the organic waste, Pakistan already has the recorded evidence on kitchen gardening and composting. However, there is still the need to educate the public on waste segregation at source and benefitting from the large percentage of organic waste.

Chapter 4 Findings and Analysis

4.1 Circularity Options for Bahawalpur and Gujranwala

The flow charts below (Figure 4.1 and 4.2) were created using SankyMatic[1]. From those diagrams the waste management processes can be clearly visualized that take place in Gujranwala and Bahawalpur. Gujranwala being the more populous city, produces much more waste than Bahawalpur.

The diagram for Gujranwala, highlights how more waste goes unmanaged than is formally and informally collected. While the unmanaged waste for Bahawalpur was relatively low, it still reflects the lack of capacity of public institutions to manage city waste, as well as reflects the potential for managing this waste through focused interventions and protecting the environment (land and water).

Pakistan currently has designated landfill sites in only three cities: Lahore, Karachi and Islamabad. This suggests that waste collected by the formal sector is dumped on open grounds without any treatment, polluting the groundwater with leachate, polluting the air and contributing to GHG emissions by natural decomposition of waste. These dumps are a source of methane emissions, given the high organic content of the waste, that can be captured and utilized further. MSW has the potential to be a valuable renewable energy source if appropriate policies and waste management technologies are implemented.

[1] https://sankeymatic.com/build/

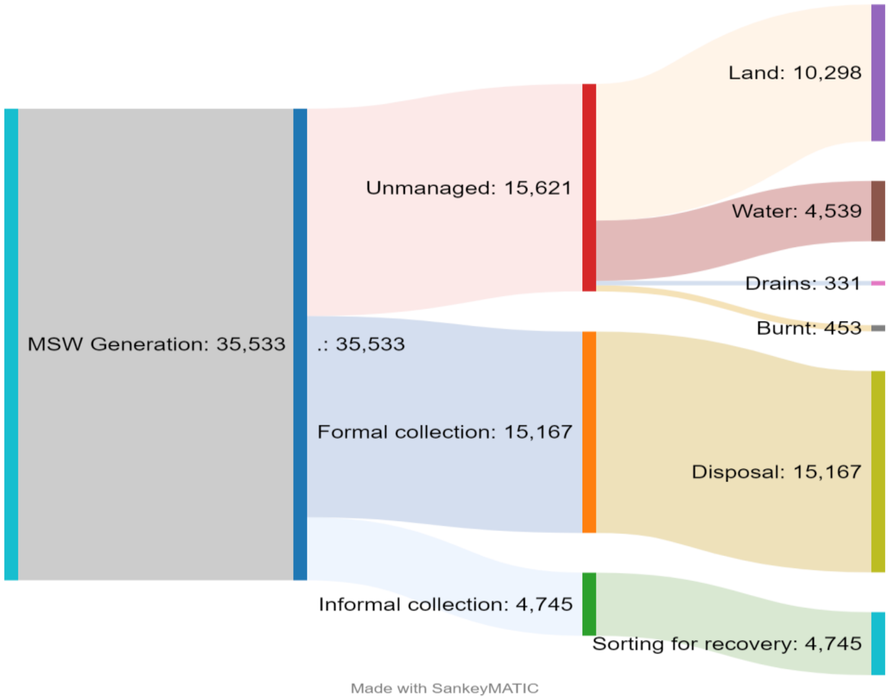

Figure 4.1 Gujranwala Waste Stream (generation, collection and disposal)

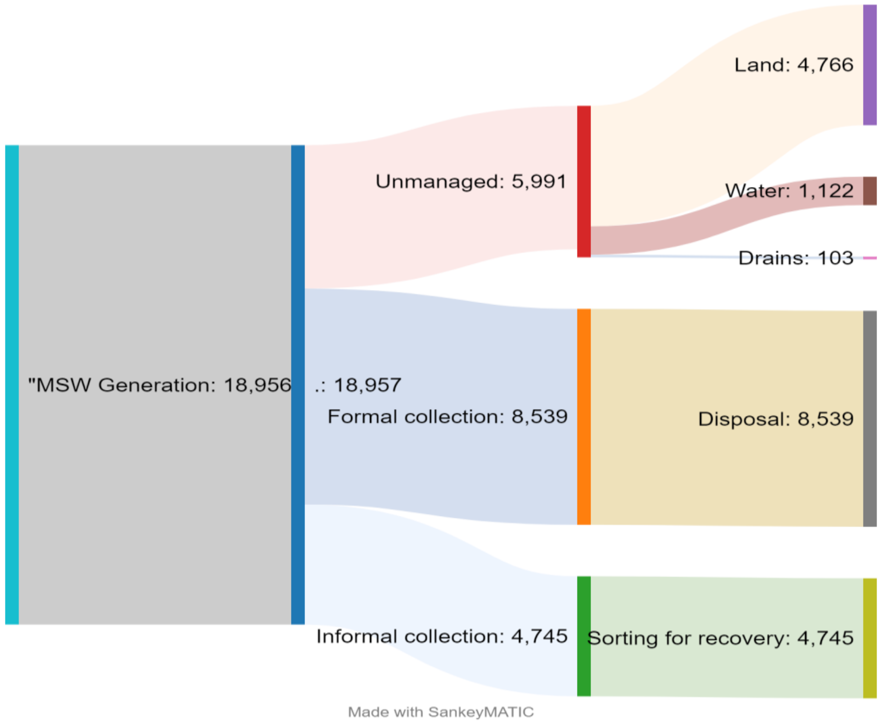

Figure 4.2 Bahawalpur Waste Stream (generation, collection and disposal)

4.1.1 Unmanaged Waste and Disposal streams:

Using equation 1 detailed in section 3.1, the following analysis has been conducted for unmanaged (waste that is not collected) and disposal (waste that is collected and disposed at open dumps) waste streams. The appropriate choice of discount factor remains the subject to debate ever.

Cost Benefit Analysis

	Gasification	**Incineration**	**Pyrolysis**
TF (PKR million/year)	0	0	0
Q_k (MWh/Year)	24090	21353	24090
P_e (PKR/kWh)	12	12	12
B_k (PKR million/year)	289080	256236	289080
C_k (PKR million/year)	930.75	744.6	930.75
Profit	288149.3	255491.4	288149.3
Sum of Present value of cashflows	1902363	1686756	1902363
CAP_k PKR Million	3200	2352.8	5666.61
CBA	**1899163**	**1684403**	**1896696**

The CBA values describe the benefit each option offers of shifting from traditional method of disposing waste on land/open dumps to WtE technologies. The dumping of waste and not utilizing it for electricity generation not only means that an economic opportunity is missed but it also is inducing negative cost of transporting the waste and environmental impacts. These results show that the highest positive CBA is for gasification followed by pyrolysis and incineration. This means that most profitable technology is gasification. The product of gasification is a syn gas[2] that can be used as a direct substitute for natural gas and other fossil fuels in the production of heat, steam or power. The gasification technology is preferred over pyrolysis and incineration as it provides greater fuel flexibility and syn gas versatility. Given the resource and energy crisis in Pakistan, utilizing WtE technologies for tapping indigenous resource for energy is way forward.

[2] The syngas is mainly composed of CO, H_2, N_2, CO_2, and some hydrocarbons (CH_4, C_2H_4, C_2H_6, etc.). Very small amounts of H_2S, NH_3, and tars may also be included

Given these stats, the quantities of waste reaching the land or open dumps are greater for Gujranwala showing an opportunity to consume this waste and invest in WtE technology. The potential exists if unmanaged waste also is recycled as a priority and as a last resort utilized for WtE to stop the land and water pollution. As for the open burning, it must be banned and should be replaced by WtE technology to operationalize circularity. The shift from WtE and other cleaner methods is usually halted by the nonavailability of funds. This change can now be made possible if there is a strategy at national level informed by a circular economy vision. The section 4.4 will cover this in detail.

4.1.2 Managed Waste through informal collection:

Waste items included under this category include glass, plastics, metals, paper, electronics, and textile. The waste recycling sector in Pakistan is completely informal (Nawaz M. M.-M.-M., 2021). The informal sector includes autonomous waste pickers, itinerant waste cart holders, and small unregistered shops who buy recyclables as a side business. Hence, informal channels are well established for recycling. The role of informal sector in waste management is not well-documented even though it acts as a helping hand to the formal sector. Limitations like low technology, lack of work permits, small-scale work, unregistered operations, labor-intensive work, and self-administered working limit efficiency of the informal sector.

The formal systems do not acknowledge or recognize the contribution of the informal sector due to its misalignment with the set waste management systems. In addition, the informal sector remains unregulated due to lack of licensing which incurs the operators free of taxes but also devoid of the formal welfare schemes of the government (Darbi, 2018). Because the formal sector's regulation doesn't extend to the informal sector, massive violations of human rights and lack of inclusivity persist there. Degraded working situation forces the employees of informal sector to encounter occupational hazards and perform in unsanitary environments without proper gear. Women, children, and religious minorities are mostly tasked with low level and hazardous jobs such as waste scavenging and dealing with filthy hazardous waste.

Among both Bahawalpur and Gujranwala, it is observed that Bahawalpur is recycling a whooping 52% of its generated MSW while numbers for Gujranwala are relatively low i.e. 13% (figure 4.6 and 4.7). Even though, the recycling in both cities is dependent on the informal sector especially in the areas where public or private service companies do not operate, the efforts of such intermediaries of waste management value chains remain unaccounted and undocumented. This leads to a huge gap in data and information that is needed for the development of a robust circular economy system. The enablers discussed later in section 4.4 will cover the role of entities to overcome this barrier.

In addition, the WtE operation (gasification or pyrolysis) with high organic content can generate economic and environmental benefits as discussed earlier. The informal sector plays a major role in waste minimization efforts. Since, informally waste is collected to be sold as a raw material, it is appropriate to say that the circularity is currently being achieved here.

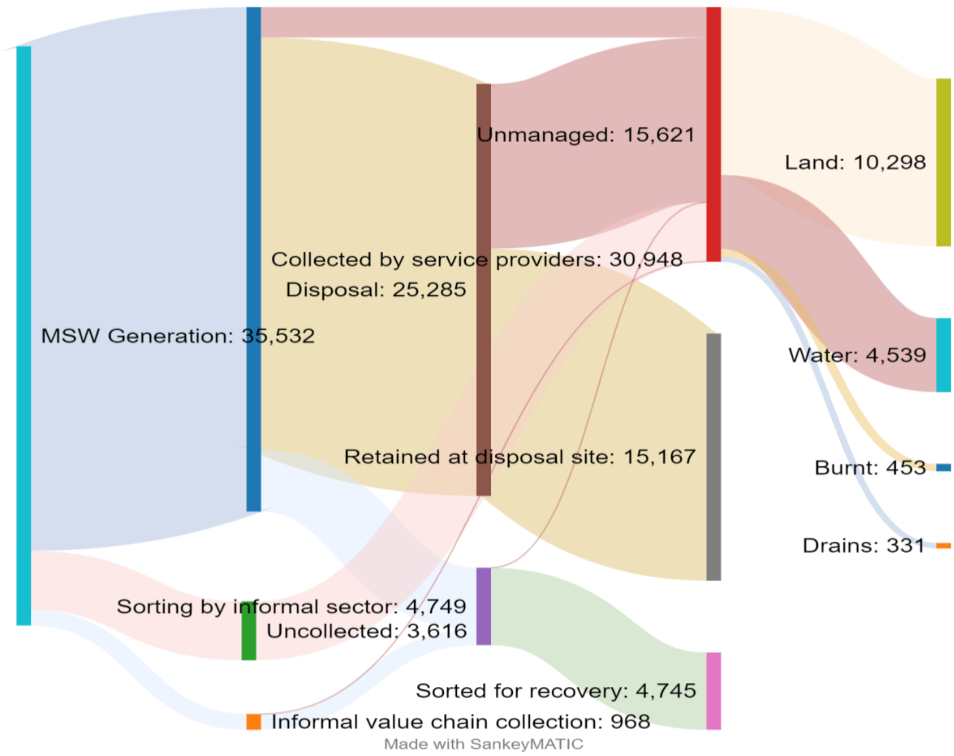

Figure 4.3 Management of MSW for Gujranwala

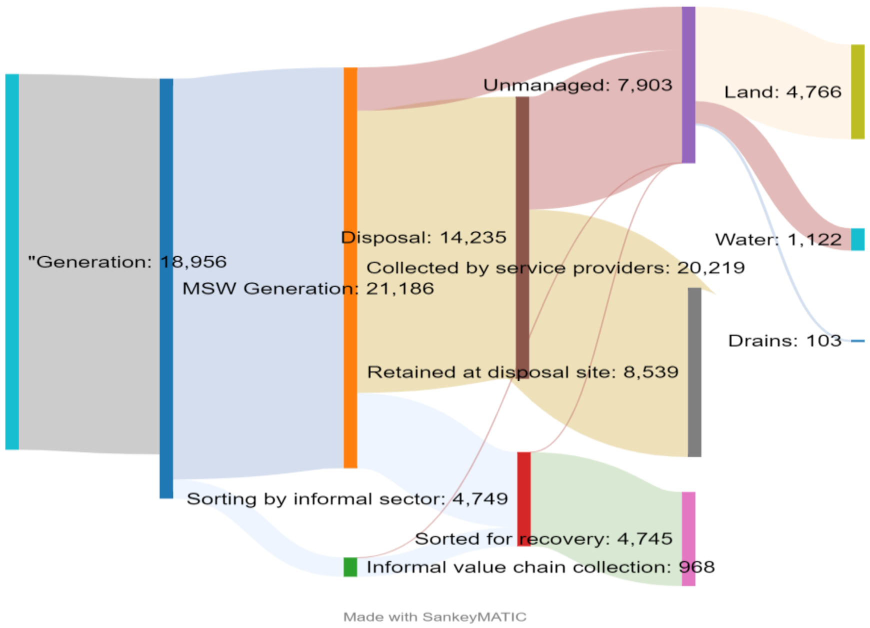

Figure 4.4 Management of MSW for Bahawalpur

4.2 Creating an enabling environment for Circular economy in Pakistan

Although, Pakistan has certain case-by-case regulations (NEPRA's Competitive Upfront Tariff for waste to energy projects), policies (Pakistan NDC), action plans (NAP-SCP), and programs that contribute to the circular economy. However, advancing a circular economy model needs a long-term vision or a clearly defined strategic goal based on country context. This is needed to provide a direction to all the interested parties and also enables the government to record progress. In this way, the role of public sector is vital to initiate a dialogue with all stakeholders to create an ownership and gather consensus of the larger audience for circular economy. Therefore this section will cover the important elements of an action plan that a public entity like Ministry of Climate Change or Ministry of Finance needs to initiate to transition to a circular economy.

4.2.1 Promoting circular practices through policies, standards, levies and bans

Historically, Pakistan's approach has been based on managing the waste and embracing the 3R principles. It was until the development of NAP-SCP in 2017 that the scope was expanded to resource efficiency, sustainable consumption and production. Even with the existing frameworks, the implementation is not substantial and require supporting legislations.

Literature suggests that there are essentially three areas that can pave way for a Circular Economy future:

4.2.1.1 Policies for reuse, durability and reparability, and remanufacturing:

The NAP-SCP covers these elements for different sectors including food, waste, transport, etc. However, the gap exists in implementation that can be overcome by supporting regulations. One good example to support this is landfill tax imposed by EU countries. 20 EU member countries have landfill taxes in place that helps drive waste away from landfill towards preferable alternatives. Among these, seven countries have banned post-consumer plastic waste from landfills and diverted high rates of plastics towards energy recovery.

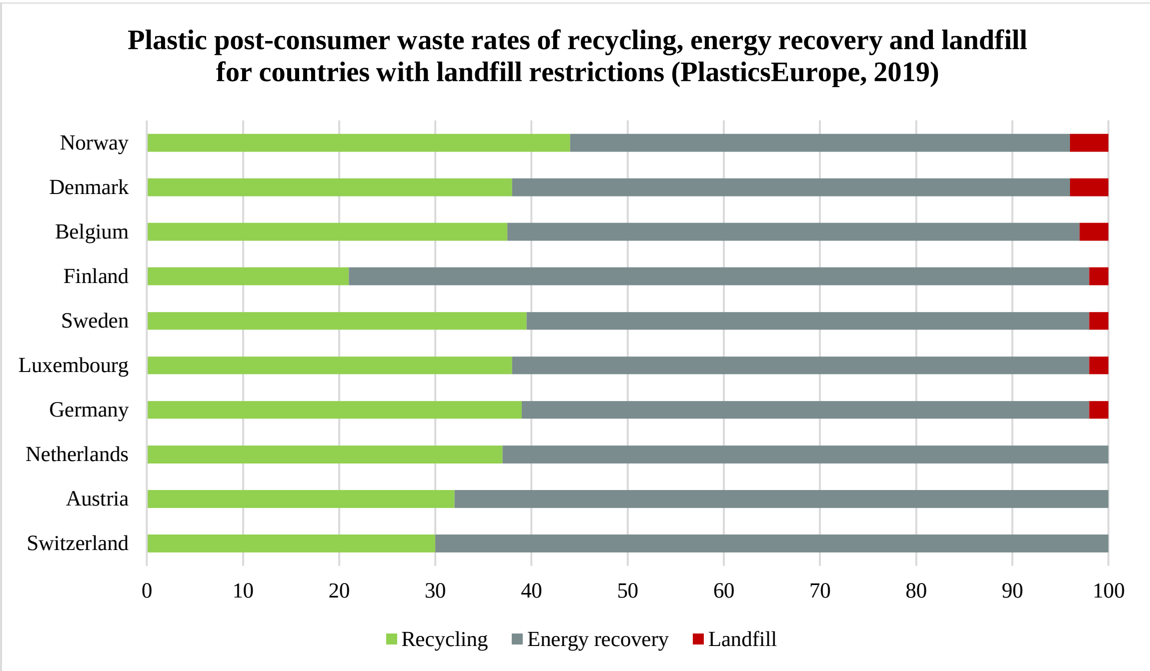

Figure 4.5 Plastic post-consumer waste rates of recycling, energy recovery and landfill for countries with landfill restrictions

Source: (PlasticsEurope, 2019)

These restrictions when combined with other form of measures can derive good results. For example '**Pay-as-you-throw' schemes** at local house-hold level that charges household on the amount of waste they generate. This incentivizes the residents to sort waste facilitating waste segregation at source. This scheme complements and helps transitioning to circular economy.

Other supporting regulations include:

- Consumption Reduction Targets: set national reduction targets, to reduce the use of items like plastics plastic bags etc. while making alternative products available. Pakistan can scope out the single-use plastics used at restaurants and hotels with voluntary agreements between restaurants, suppliers and the Ministry of Climate Change. The restaurants and hotel chains can improve their sustainability performance by taking such initiatives. The success of such measures could be enhanced by legislating minimum targets for restaurants and hotels and committing to Sustainability Achiever awards from government

- Extended Producer Responsibility: Based on the concept of the “polluter pays” principle, EPR is a market-based instrument that obliges producers to share the cost of waste management and incentivizes producers to develop alternatives. Adopting EPR helps promote recycling and closing the loop to achieve a circular economy. Pakistan can adopt this measure with a lot of recycling options available domestically.

- Separate Collection Objective: Deposit refund schemes are systems where consumers buying a product pay a small amount of money which will be reimbursed when they bring the container to a collection point once they have finished using it. The container can then be recycled and transformed into secondary raw materials.

- Product Design Requirement: This measure requires companies to design their product while keeping in mind the recycle option. In the context of Pakistan, voluntary agreement with beverage companies to design beverage containers that can be recycled completely, including the lid, will divert waste from landfills and dump-sites.

- Legal framework for controlling plastic pollution should be introduced by the environmental protection agencies (federal and provincial) with a holistic approach to industrial sector development including environmental sustainability, skills development, export promotion and technology upgrading.

4.2.1.2 Policies for improving secondary materials markets

As described earlier, Pakistan’s recycling sector is led by informal sector where lack of data and information poses risk of inconsistent transactional costs, unregulated occupational health and safety and human rights violations like child labour. To cater these issues, formalization of informal sector has long being discussed in Pakistan and has been researched. However, there is still no substantial effort on the part of the government to achieve this. One body of research suggests that formulating strategic alliances can help regulate the informal sector through participatory dialogue. In addition, the creation of quality standards for secondary/recycled material should be developed to achieve the circular economy. This will allow for improving the quality of recycled material through innovation in technology. Such standards can be developed and implemented by Pak-EPA and Pakistan Standard and Quality Control Authority PSQCA.

4.2.1.3 Green public procurement

The concepts of green procurement or green purchasing policy have been adopted by private sector largely where the corporates have set their sustainability agendas and utilize this policy to meet their climate change commitments. In Pakistan, such policies at public sector level are absent. Being a large consumer of goods and services, this serves an untapped potential for Pakistan to substantiate circular economy.

4.2.2 Fiscal Measures

Evidence on transitioning to circular economy suggests that investments in circular economy infrastructure and model for developing countries is risky (Schröder, 2021). For example, investing in landfill gas collection system with uncertainty in future waste availability poses greater risk and is traditionally weighed against the benefits of short-term benefits from linear economy. Therefore, taxes and subsidies should be implemented to de-risk the transition. One good example of such a tax is reducing the subsidy on fossil fuels and increasing on renewables so that adoption of clean energy is upscaled. Figure 4.6 shows an example of taxation framework that can be adopted by countries to achieve circular economy.

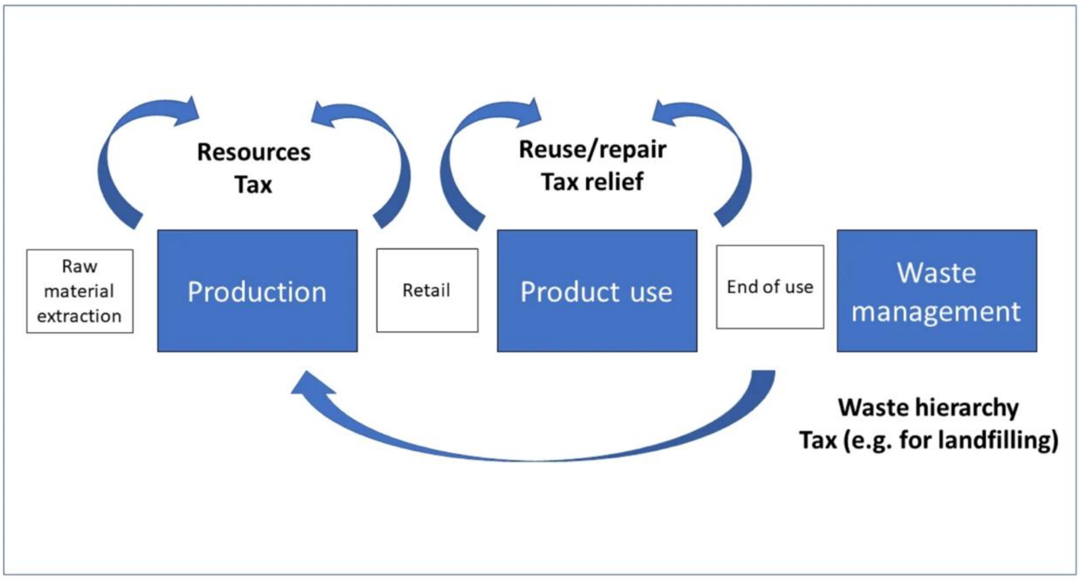

Figure 4.6 Taxation Framework for Circular Economy

Source: (Milios, 2021)

One thing to note here is that before making these decisions, it will be important for government to involve all stakeholders to gain larger consensus and disseminate important information to provide clarity on taxes or subsidies.

4.2.3 Financial Support

The transition to circular economy is technology intensive. For developing countries like Pakistan, where budget allocations are prioritized based on immediate social and economic benefits, international financial support becomes a vital source to reach the financial targets needed for circular economy. Therefore, the information on grants, direct and indirect investments made available through development sector, bilateral cooperation and international community forums need to be gathered and published. Pakistan has already benefitted from international support for meeting the SDGs and climate commitments and the important one to mention here is the support from EU that has supported Pakistan's public and private sector on the areas of waste management, resource efficiency and circular economy. Similar continued support from international community is important for Pakistan to overcome fiscal barriers.

4.2.4 Public Private Partnerships:

Evidence suggests that Public-private partnerships PPPs are vital to drive transition to circular economy. As explained earlier, innovation in technology, technical capacity and finance are important to achieve circularity targets and private sector can help mobilize additional resource for this. Pakistan has already highlighted in its NDCs as well as in NAP-SCP the need for PPPs to facilitate innovative, and green financing. For a shift towards renewable energy through PPPs, government is also defining regulatory structures e.g. recent USD 500 million Green Bond (WAPDA's Indus Bond). In future, Pakistan is also looking at certain potential opportunities to mobilize private finance for priority areas like waste to energy projects. Also, private waste management sector in Pakistan is outperforming the public sector- both in terms of innovation and infrastructure. Therefore, this partnership can be leveraged to share the information to benefit from the experience.

4.2.5 Capacity Building

Circular economy is rather a new concept for Pakistan. Therefore, education, awareness and training of government, businesses, and society is vital. The waste management sector in Pakistan has long suffered due to the lack of technical and human capacity. Therefore, financing such initiatives must be prioritized. In addition, launching educational material and making such concepts a part of the national curriculum will boost innovation as well as will contribute towards technical human resource. Private sector will need to take initiatives on their own to develop the capacities on sustainable design and procurement for transitioning to circular economy model.

4.2.6 Data and Information:

To measure the performance against the circular economy vision, it is important to collect and maintain the data against set of indicators. The assessments done globally on achieving the circular economy targets is still nascent and researchers claim that there are elements of circularity that need data that has never been traditionally measured. Therefore, this will be a challenge for Pakistan, already being a data deficient country. The use of IT system is suggested as one of the solutions where EU has adopted the way to use "digital fingerprints[3]" to help derive the lifespan of digital products like laptops, phones etc. The age distribution of devices in use and their service life estimates help inform the decisions on circularity of materials. This digitalization of information has generated new data stream that can help monitor products from utilization to wastage. The process is still is in its infancy but further research in the utilization of this data can benefit the product circularity planning.

In addition, to monitor the impacts of circular model on environment is also novel for Pakistan. Although, Ministry of Climate Change has initiated natural capital accounting but modeling a connect between waste sector and natural capital is long way for Pakistan. In conclusion, Pakistan needs to identify a set of indicators to monitor progress and build capacities of data compilers to report on these indicators. In addition, there will be a need to continuously engage

[3] When the electronic devices connect to websites, they leave a fingerprint with information that enables sites to tailor information to that particular device. This information includes the type of device and software version.

with private sector as well as international community to gather the information on new data and tools made available to monitor progress.

Chapter 5 Conclusion

The circular economy is a systems solution framework that aims to close the gap between the production and the natural ecosystems ’cycles. It is based on three principles, driven by design, eliminating waste and pollution, circulating products and materials (at their highest value) and regenerating nature. It is a resilient system and the goal is to preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows.

The circular economy has environmental benefits including the potential to reduce greenhouse gas emissions, use of renewable energy and energy-efficient processes will cause less pollution. Fewer materials and production processes are needed to provide good and functional products. Moreover, residues are seen as valuable and are reused in the process. According to a McKinsey report, the circular economy has the power to increase GDP with an increase in revenues from new circular activities, together with cheaper production and therefore economic growth. The social benefits include the creation of jobs. It will also produce savings for families in the form of lower costs of primary resources.

5.1 Key Findings and Utility

The main objective of the study was to create a baseline assessment of current circular economy potential and to suggest the ways to pilot circular economy system in Pakistan. There have been efforts previously on promoting waste to energy and improving waste management through privatization. However, nothing substantial in terms of transitioning to circular economy has been achieved by Pakistan.

The study finds that

- In Pakistan, the data is lacking which makes it difficult to design and implement circular economy models
- Waste composition of Bahawalpur and Gujranwala have highest organic waste highest percentage followed by Plastics and paper. All these categories have high circularity potential.

- Unmanaged waste percentage for Bahawalpur and Gujranwala reflects the lack of capacity of public institutions to manage city waste, as well as reflects the potential for managing this waste through focused circular economy interventions
- The cost-benefit analysis shows that the most feasible technology for waste that ends up on the land (open dumps) is gasification followed by pyrolysis and incineration.
- Bahawalpur is recycling a whooping 52% of its generated MSW while numbers for Gujranwala are relatively low i.e. 13%.
- Any recycling happening in Pakistan is through informal sector that largely remains unregulated, unaccounted and undocumented.
- The proof of the concept of circular economy exists where certain nations have adopted and piloted the system and are looking forward to bring it to scale. Whereas, countries like Pakistan are still struggling with the lack of data, capacities and legislative environment to bring about this change

Further, the study identifies and suggests measures to create an enabling environment for Pakistan to transition to a circular economy model. This will require the participation of all the actors in the value chain as well as the decision-makers, donors and researchers. The recommendations include:

- The role of public sector is vital to initiate a dialogue with all stakeholders to create an ownership and gather consensus of the larger audience for circular economy
- Even with the existing frameworks, the implementation is not substantial and require supporting legislations like levy on fossil fuels, creating standards for recycled products, green purchasing policy for public sector, etc.
- Disseminating the information on grants, direct and indirect investments made available through development sector, bilateral cooperation and international community forums for filling the financial gap
- Leveraging Public-private partnerships to drive transition to circular economy. Innovation in technology, technical capacity and finance are important to achieve these targets and private sector can help mobilize additional resource for this
- Education, awareness and training of government, businesses, and society is vital
- Identify a set of indicators to monitor progress and build capacities of data compilers to report on these indicators.

5.1.1 Implications for Public and Private Sector:

The study successfully identified the potential economic benefits of diverting the waste from landfills and presents a framework of action needed from government counterparts to support the transition. Private sector is a key stakeholder in realizing the paradigm shift to circular economy and government has previously taken steps to encourage private sector to play their role in waste management e.g. NEPRA's upfront tariffs for waste to energy plants. Still, there are economic and fiscal, institutional, technological and regulatory barriers that need to be addressed for greater private sector involvement. The research successfully identifies the areas of action where public sector can focus and deliver to realize the circular economy agenda and meeting the NAP-SCP targets. Moving ahead, it is important that public sector expands the forms of collaboration with different stakeholders and adopt multi-actor approach to develop and promote effective enabling environment for circular economy. Evidence suggests that private actors can influence the transition by idealizing the circular economy, collaborating among peers for novel technologies, co-creating across value chains and supporting skill development and awareness. The current study is based on literature and can be further enriched wirh stakeholder consultations. Despite this, the current findings will benefit both public and private partners to conceptualize and operationalize circular economy.

5.2 Future Research

Moving ahead, it is suggested that focused analytical researches are conducted to identify the potential of circularity and help policy-makers to develop a waste management solution. The adoption of innovative technologies for upcycling waste is highly dependent on the costs, i.e. a solution is adopted only if it is economically beneficial. This benefit is not just in terms of the economy but also in social and environmental terms. Further studies based on environmental and social indicators of the circular economy must be studied to help boost the adoption of inclusive circularity and materializing the concepts of ‘Just Transition’.

Annex 1: Primary Data Collected

A. Gujranwala

Item	Description	Unit	Value
Population	How many people live in the area (city, urban district, region) you want to model?	Persons	2,765,000
Municipal solid waste generation per capita	How much municipal solid waste per person is produced per day ?	Kg/capita/day	0.43
Municipal solid waste composition	Paper	Weight-%	16%
	Plastics	Weight-%	8%
	Glass	Weight-%	1%
	Metals	Weight-%	0%
	Other	Weight-%	15%
	Organic	Weight-%	59%
Item	**Description**	**Unit**	**Value**
How much MSW is disposed of in disposal facilities?	Paper	Tonnes/day	136.8
	Plastics		69.3
	Glass		10.8
	Metals		1.8
	Other		126.7
	Organic		504.6
How much MSW is sent to energy from waste?	Paper	Tonnes/day	0.0
	Plastics		0.0
	Glass		0.0
	Metals		0.0
	Other		0.0
	Organic		0.0
	Paper	Tonnes/day	0.0

How much MSW is sorted by the formal sector for recovery?	Plastics		0.0
	Glass		0.0
	Metals		0.0
	Other		0.0
	Organic		0.0
How much MSW is sorted by the informal sector for recovery?	Paper	Tonnes/day	8.0
	Plastics		13.0
	Glass		5.0
	Metals		1.5
	Other		6.0
	Organic		0.0

B. Bahawalpur

Item	Description	Unit	Value
Population	How many people live in the area (city, urban district, region) you want to model?	Persons	850,000
Municipal solid waste generation per capita	How much municipal solid waste per person is produced per day ?	Kg/capita/day	0.47
Municipal solid waste composition	Paper	Weight-%	6%
	Plastics	Weight-%	13%
	Glass	Weight-%	5%
	Metals	Weight-%	1%
	Other	Weight-%	27%
	Organic	Weight-%	48%
Item	**Description**	**Unit**	**Value**
How much MSW is disposed of in disposal facilities?	Paper	Tonnes/day	16.0
	Plastics		39.0
	Glass		15.0
	Metals		2.5
	Other		102.0

	Organic		192.0
How much MSW is sent to energy from waste?	Paper	Tonnes/day	0.0
	Plastics		0.0
	Glass		0.0
	Metals		0.0
	Other		0.0
	Organic		0.0
How much MSW is sorted by the formal sector for recovery?	Paper	Tonnes/day	0.0
	Plastics		0.0
	Glass		0.0
	Metals		0.0
	Other		0.0
	Organic		0.0
How much MSW is sorted by the informal sector for recovery?	Paper	Tonnes/day	8.0
	Plastics		13.0
	Glass		5.0
	Metals		1.5
	Other		6.0
	Organic		0.0

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