CLIMATE RESILIENCE APPROACH TO SUSTAIN THE SOLID WASTE SECTOR THROUGH ANALYTICAL HIERARCHY PROCESS (AHP) FOR POLICY DECISION

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ABSTRACT

Pakistan is fifth most populous country in the world with solid waste generation of 46 million tons per year. The waste collection efficiency is reported at about 55%. Under devolution, all provinces have an opportunity to design and invest in the waste sector. The Punjab has adopted local outsourcing model across the whole province for waste collection, transportation, and disposal. Further, government of Punjab has notified Suthra Punjab Authority Ordinance on 27th November, 2025 to establish Suthra Punjab Authority along with establishing Suthra Punjab Agencies at the district level. In Sindh province, Sindh Solid Waste Management Board is responsible for provision of cleanliness services by opting outsourcing model. Khyber Pakhtunkhwa has established seven Water and Sanitation Services Companies at divisional headquarters by following insourcing model in urban areas. Baluchistan has outsourced the waste services at Quetta city under Safa Quetta Project. Azad Jammu and Kashmir has opted insourcing model with procurement of new machinery for Muzaffarabad. Islamabad, the capital city of Pakistan has initiated the tender for outsourcing of waste collection, treatment and disposal. In the absence of any sectoral policy, all provinces are still struggling with manual sweeping, outdated waste collection fleet, and open disposal without resource recovery at formal level.

As per physical composition, the governing component is organic/ kitchen waste which is found at 53.98% followed by plastic at 11.55 % and diaper 9.08% at national level. The chemical composition of waste shows the high moisture and ash contents at 50.5% and 21.2% respectively. The waste sector is responsible for emitting 26.5 million tons of CO_2-eq greenhouse gas per annum from generated waste. The sector has potential to reduce 73% emissions by adopting strategy for waste diversion from landfilling. The economic cum environmental monetary including carbon credit potential of the waste sector can contribute in reducing about 40% sectoral expenditure as compared to business as usual (BAU), thus stepping the sector towards financial sustainability.

We have applied Multi-Criteria Decision-Making approach such as Analytical Hierarchy Process to prioritize the municipal solid waste treatment and disposal options. The recycling is found on rank one, followed by composting and landfilling with gas recovery. However, landfilling with gas recovery is found as option one based on cost benefit analysis that is found aligned with BAU scenario. We also proposed policy guidelines to align the waste sector with principles of circular economy, targets for National Determined Contributors and Sustainable Development Goals. This research work has the enormous potential to initiate the sector suitability if implemented by the Government of Pakistan.

PREFACE

This research report is a result of support from the RASTA PMU Team, the Planning Commission of Pakistan, and the leadership of the worthy mentors. This research provides an in-depth look at the pressing challenges, untapped opportunities, and emerging trends present in the solid waste management sector, with a focus on all provinces within the country's devolved governance system. Pakistan, grappling with increasing waste generation and low resource recovery rates, faces pressing environmental, financial, and operational challenges within its solid waste management sector. In the context of growing urbanization, this work critically examines waste composition, greenhouse gas emissions, and institutional and governance frameworks, shedding light on current management practices and pathways for sustainable transformation. The study employs a Multi-Criteria Decision-Making framework, including the Analytical Hierarchy Process (AHP), to evaluate and prioritize cost-effective waste treatment options. It also formulates practical policy guidelines that are aligned with circular economy principles, Nationally Determined Contributions (NDCs), and Sustainable Development Goals (SDGs).

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ABBREVIATIONS

SWM	Solid Waste Management
MSW	Municipal Solid Waste
GHG	Greenhouse Gas Emissions
EQT	Emission Quantification Tool
IGES	Institute for Global Environment Strategies
WDR	Waste Diversion Rates
MCDM	Multi-Criteria Decision Making
AHP	Analytic Hierarchy Process
WCS	Waste Characterization Study
WGR	Waste Generation Rate
WCE	Waste Collection Efficiency
EMV	Environment Monitory Value
RDF	Refused Derived Fuel
MRF	Material Recovery Facility
AD	Aerobic Digestion
LFG	Landfill Gas Recovery
STD	Segregation Treatment and Disposal
SC	Scenario
BC	Black Carbon
SLCP	Short-lived Climate Pollutants
CW	Collected Waste
DW	Diverted Waste
OM	Organic Matter
C: N	Carbon to Nitrogen Ratio
COM-B	Capacity, Opportunity, and Motivation model of behavior
OPEX	Operational Expense
CAPEX	Capital Expense
CBA	Cost-Benefit Analysis
EMV	Environmental Monetary Value

INTRODUCTION

1.1. Solid Waste Challenges

Pakistan is the fifth most populous country in the world, with a population share of 241 million and generating approximately 38 million tons' solid waste per annum (Iqbal et al., 2023), with annual growth rate is more than 2.4% (Chatha et al., 2025). A high rate of socioeconomic development has resulted in a large quantity of Municipal Solid Waste (MSW) generation, pressing need to improve inefficient and ineffective waste management systems, thus leading towards mitigation of environmental and public health hazards. As a result, Solid Waste Management (SWM) has become a socio-economic emergency (Rashid et al., 2025). In Pakistan, the stages of municipal waste collection include two phases that are primary and secondary collection (Mahmood & Khan, 2019). Approximately 90% of the collected waste is destined in open dumping sites, where it left neglected without resource recovery (Atta et al., 2020). In densely populated cities, only 60% of waste is collected, while uncollected MSW is responsible for urban flooding, environmental degradation, and serious public health risks through disease vectors (Mousavi et al., 2023).

1.2. Climatic Impact of Waste Sector

The emission of methane (CH4) from MSW is one of the major contributors to greenhouse gas (GHG) (Sohoo et al., 2022), thus inefficient handling contributes a fair number of emissions to the environment. Pakistan's waste sector including sludge waste produces about 32 Million tons (Mt) of CO2-eq per year which is constituting approximately 6% of the total national emissions, i.e., 585 Mt of CO2-eq (UNFCC-BUR-1, 2022). A truly enormous, one illustration can be seen in the Lahore Lakhodair disposal site, which is contributing 12.8% of GHG to the total city level emissions. Disturbingly, this tendency is increasing as CH4 levels at Lakhodair have soared 15-fold since 2015, illustrating a dire situation that requires urgent attention of policymakers to explore the methods to transform this environmental challenge into climate funding opportunity (Maasakkers et al., 2022). The sectoral regulations and waste landfill diversion strategies towards recovery of recyclables, composting, Anaerobic Digestion (AD) and final disposal with Landfill Gas (LFG) recovery can contribute in emissions reductions in Pakistan (Devadoss et al., 2021).

1.3. Sectoral Policy and Institutional Challenges

In the absence of any formal policy at national and provincial levels, it is a critical challenge for policymakers to sustain the sector in Pakistan. Under the 18th amendment, all provincial governments have autonomous rights to fund and execute the sanitation services through Local Government and Community Development (LG&CD) departments. The provincial governments have allocated approximately PKR 221 billion in FY 2025-26 for the waste sector. The government of Punjab with national population share of 68% is spending PKR 150 billion, Sindh government with population share of 20% is spending PKR 43 billion, Khyber Pakhtunkhwa (KPK) government with population share of 8% is spending PKR 17.3 billion, Baluchistan government with population share of 4% is spending PKR 8 billion, and Azad Jammu and Kashmir (AJ&K) and Islamabad governments are spending about 2% of the total waste sector budget (Iqbal et al., 2024). Despite spending reasonable sectoral budget, i.e., 1.26% of the national total budget, the waste sector is still considered as liability due to huge investment and workforce in absence of any waste diversion regulations, strategies and policies. However, the informal waste sector is recovering an average 14.4% of recyclables from municipality waste stream and this stakeholder's role is totally ignored in the current outsourcing model in Punjab, Sindh, Baluchistan, and Islamabad regardless of its effort towards minimizing waste handling cost and emissions reductions. The outsourcing models are designed without engaging the relevant stakeholders which reflect weak institutional capacity at part of sate run waste sector.

1.4. Objective of Study

1. To estimate the waste sector emissions generated from sources, i.e., waste collection, transportation, burning, and open disposal
2. 2. To evaluate the sectoral economic and environmental potential for waste diversion from landfilling and related contribution towards emissions reduction and climate resilience.
3. Gaps identification at the institutional and policy levels that hinder sectoral performance.

1.5. Scope of the Research Work/ Study

The scope of the study covered the following key components:

Geographic Coverage: Approximately 30% population of Pakistan including major cities of Punjab, Sindh, KPK, Baluchistan, Islamabad and Azad Jammu and Kashmir (AJK), representing diverse urban typologies from large metropolitan cities to smaller districts and towns.

Solid Waste Sector Emissions Inventory: First step is to collect the data on waste characterization of major cities including Lahore, Rawalpindi, Gujranwala, Multan, Faisalabad, Sahiwal, Islamabad, Karachi, Quetta, and Muzaffarabad.

a. **Waste Sampling Locations:** Waste samples were obtained from vehicle load such as transfer stations, dumpsites, or designated sorting areas where primary collection vehicles deliver waste collected from residential, commercial, and institutional sources.
b. **Waste Sample Size and Methodology:** We followed "Waste Wise Cities" Module 3.3 – WaCT Step 6: Waste Composition at disposal site/ vehicle load under United Nations (UN) Habitat guidelines (UN-Habitat, n.d.). For each city, a mixed physical waste sample of approximately 300–500 kg was obtained and reduced to a representative sample. i.e., 70-100 kg, using the Quarter Coning method to ensuring statistical representativeness (SSIA, n.d.).
c. **Waste Physical Characterization:** Manual sorting of waste into 14 predefined categories, such as food waste, plastics, metals, paper, textiles, etc., with precise weight measurements for each.
d. **Waste Chemical Analysis:** For chemical analysis of the MSW, we followed American Society for Testing and Materials (ASTM) standards (ASTM, n.d.). Laboratory analysis of sub-samples to determine chemical attributes such as moisture content, organic matter, C:N ratio, ash content, calorific value, and nutrient profiles.
e. **Allied Data on Current SWM Situation:** Primary data on climatic classification of each city, MSW quantity generated, physical composition of waste, consumption of fuel, i.e., diesel and petrol issued to fleet for waste collection, electricity requirement, waste diversion, waste disposal, dumpsite location and distance from city center, and recyclables recovery, was

obtained from the relevant municipality/ WMC. Such type of the data is essential to calculate the GHG emissions under Business as Usual (BAU) scenario.

Prioritization of Waste Treatment Options: Prioritizing the MSW treatment options such as composting, recovery of recyclables, Anaerobic Digestion (AD), incineration, refuse derived fuel (RDF), and landfilling with LFG recovery by following the scientific reasoning such as Multi Criteria Decision Making (MCDM) approach.

Emissions Reduction/ Environmental Potential from MSW Treatment: Scenarios are developed for each provincial headquarter for estimation of emissions reduction potential by comparing available MSW treatment options under local conditions. The emissions reduction potential is further calculated and projected for whole province under the bottom-up approach.

Economic Potential of Recyclables: The quantity of each recyclable such as paper, plastic, glass, metal, combustible etc. is projected based on physical composition and city's waste generation rate. The recyclables quantity is further converted into economic value from the respective of recycling with the objective to integrate the sector with principles of Circular Economy (CE).

Estimation of Sectoral Carbon Credit Potential: Sectoral emissions reduction potential of various treatment options is further compared with the BAU scenarios. GHG emissions saving are converted into monetary value to determine the sector potential for carbon credits.

Waste Sector Policy Guidelines: MSW policy guidelines are also proposed for the policymakers, leaders, and federal Ministry for Climate Change and Environmental Coordination (MoCC&EC) to sustain the local waste sector in Pakistan.

Study Limitation: In this study, we only considered MSW generated from households and commercial entities for characterization and emissions inventory, excluding other waste streams, i.e., hospital, industrial, and Construction and Demolition (C&D) waste.

LITERATURE REVIEW

2.1. Background

The MSW management is often overlooked in environmental management schemes in many developing countries (Batool et al., 2008). Waste management is a multidimensional problem that requires critical assessment of its environmental effects, technical aspects, mode of implementation, and its financial implications based on modes of treatment and disposal. Urgent environmental concerns, the scarcity of resources, the reality of climate change, and a commensurate rise in awareness and community engagement have all led to this notable change (Khisro et al., 2024). Baseline data on waste composition, waste generation, treatment, and disposal along with climate impacts, are required for making informed decisions on how we can optimally minimize the possibility of environmental hazards and maximize resource recovery. By immersing ourselves greatly into the intrigues of the system, we can propose the measures that not only safeguard the environment but also exploit what we have to fulfil its potential (Majeed et al., 2018). SWM is a complex field that requires careful planning, implementation, and efficient maintenance of operations. It should be considered using cost-effective measures that are in lined with environmentally sound technologies (Iqbal et al., 2022b).

2.2. Climatic Impact and Solid Waste Management

The concept of global warming and climate change that humanity is facing is hitting an all-time high in terms of threats to society (Eckstein, 2021) The concentrations of GHGs in the atmosphere, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), have hit dangerous levels since the pre-industrial period. This drastic increase is one of the major causes of the alarming transformation in the environment that we are observing (Thomas et al., 2004). Global warming and climate change are two major challenges facing modern society. This GHG emissions increase is one of the major contributors of environmental problems (D' Avignon et al., 2010). The landfilling of MSW contributes approximately 73% to all CO_2-eq emissions in the country from the waste sector, however, the remaining 27% emissions are attributed to industrial wastewater treatment and disposal (Mir et al., 2017).

2.3. Encompassing Solutions for Solid Waste Management

In fact, the solution to the correct methods of waste collection and treatment presents a complicated issue to the municipalities and waste collection companies (Neri et al., 2017). This involves selecting appropriate sites to set landfills with integrated MSW treatment facilities however, the risk involves mindful consideration of several factors, such as ecological impact, neighborhood interests, and efficiency in the process, and finding a balance to sustain the operations (Bello et al., 2022). Research (Thaiyalnayaki & Jayanthi, 2016) shows that MSW encompasses the generation, collection, processing, and disposal with a focus on environmental sustainability. Effective planning for waste treatment and disposal depends on proper waste characterization. Recent data show interesting insights with regard to the composition of waste. In a curious relationship between nature and city living, there is a prevalence in organic waste such as food waste and garden waste, that constitutes a large percentage of the total waste at >50% (Abdel-Shafy & Mansour, 2018). Conversely, inorganic products found lesser, but also a relevant amount, being approximately 28-36%. This information gives a clear image of the ecological issues and prospects that our cities encounter in dealing with the demands of waste management.

2.4. Physical Composition and Generation Rate of Major Cities in Pakistan

Knowledge of waste composition in a particular region is important in decision-making concerning the best way of treating and disposing of MSW (Ilmas et al., 2018). The waste composition of major cities of Pakistan are presented in Table 1.

Table 1. Physical Waste Composition in Different Cities of Pakistan

City	Organic (%)	Metal (%)	Glass (%)	Plastic (%)	Paper (%)	References
Rawalpindi	63	1	19	21	11	(Ilmas et al., 2021)
Lahore	56	1.5	2.5	21	16	(Batool et al., 2008)
Islamabad	60	0.64	2.79	3.11	7.26	(Zia et al., 2017)
Peshawar	50.41	0.08	1.48	25.78	6.50	(Ali et al., 2023)
Quetta	38.6	0.05	0.33	0.34	2.87	(Quetta Municipal Corporation, 2015)
Karachi City	51.10	2.40	5.08	16.13	11.92	(Shahid et al., 2022.)

These statistics show that there is a need to introduce the practice of better waste management and composting or biogas production from MSW due to presence of high organic components. However, the foundational element for any calculation and design lies in understanding the waste generation rate of the city. These rates serve as a crucial gateway, allowing to estimate the total waste produced in the city as depicted in Table 2.

Table 2. Waste Generation Rates in Major Cities of Pakistan

City	Waste Generation Rate (kg/capita/day)	References
Lahore	0.54	(Iqbal et al., 2023)
Faisalabad	0.50	(Urban Unit , 2023b)
Multan	0.48	(Urban Unit , 2023b)
Rawalpindi	0.55	(Ilmas et al., 2018)
Islamabad	0.61	(Sandhu & Waheed, 2021)
Karachi	0.44	(Aslam et al., 2022)
Quetta	0.46	(Muhammad et al., 2024)
Peshawar	0.38	(Waqas, 2019)

2.5. Comparative Analysis of Waste Collection Efficiencies

In Table 3, the waste collection efficiencies from different cities of Pakistan are explained.

Table 3. Waste Collection Efficiency of Provincial Capital Cities

City	Waste Collection Efficiency	References
Lahore	84%	(Jabeen et al., 2017.)
Faisalabad	43%	(Iqbal et al., 2022b)
Karachi	75%	(Aslam et al., 2022)
Peshawar	40%	(Khan et al., 2024)

The major cities of Pakistan with different socioeconomic dynamics share collection efficiency rates varying from 43% to 84%.

2.6. Economy and Waste of Pakistan

On average, the cost of waste collection in urban areas on a per ton basis in the country stands at PKR 4,794 (Iqbal et al., 2022b) All metropolitan cities are currently experiencing serious waste issues and dumped heaps are seen along roads and streets because of lack of urban planning, awareness by people and inefficient infrastructure of SWM. In developing economies, 50% of municipal budget is allocated for SWM (Aleluia & Ferrão, 2016). The sustainability of SWM sector within the country can boost economy in respect of achieving self-sufficiency in fertilizer and power/energy, i.e., production of compost and biogas out of organic waste.

2.7. Sectoral Strategies and Framework in Developed and Developing Economies

The strategies devised by the developed countries include prevention of waste, recycling and resulting in waste to energy (WtE) as well as depreciating the landfill site concept (Medina-mijangos & Seguí-amórtegui, 2020). This means that an optimal setup and escalation of the level of recycling and material recovery facility (MRF), composting and the production of RDF can make the sector a sustainable with rise in the net profit cost of low-income countries (Lee et al., 2018). In addition to that recirculation back to reusable components and composting of an organic component of wastes would be more appropriate treatment options in Asian countries than incineration, WtE and landfilling (Li et al., 2015). The worldwide diversion rates are also contrasting with South America having only 11%, Canada 26%, and Australia taking the lead at 64% (Assamoi & Lawryshyn, 2012).

In the developing countries, the main concern is the lack of waste collection effectiveness and commitments to do everything possible to collect the waste from main roads and streets. It is usually the relocation of waste products from residential and commercial locations to any other distant location for disposal (Dhokhikah & Trihadiningrum, 2012). About 20% of CH_4 globally-emitting activities can be attributed to anthropogenic activities related to disposal of wastes. The estimates are production of 1328 kg of CH_4 per hour by Eastern Asia and the sub-continent countries (Clark & Paskin, 2022) through waste management activities. The provision of cleanliness services is a legal necessity, whereas local municipalities are bound to regularly perform SWM services. Nonetheless, it can be enhanced when financial resources and the technical capacity of less-developed nations are increased (Geng et al., 2009). Local solutions may be achieved through the involvement of the private sector through public-private partnership (PPP) in the outsourcing of certain SWM processes. However, the technical and administrative capacity weaknesses of local municipalities prevent them to fulfill an active role as clients, which also acts as a barrier to achieving the aimed results (Rodić & Wilson, 2017). Less developed economies can enhance the SWM system by embracing the experience of waste collection and waste endowment technologies formed in developed countries by implementing changes based on the local conditions (Ajibade et al., 2019).

2.8. Sectoral Comparative Analysis

Whereas, when reviewing the literature, it was found that there are data available related to waste sector but in minimal capacity and no study at Pakistan level which comes true to depict the waste picture has been done in this regard. A comprehensive literature review was done to understand the waste sector strategies against the parameters of waste generation, waste composition, related emissions, policy and planning tool used to conduct research. An effort is also made to conduct comparative analysis of the waste sector at national level, developed economies, regional level, and developing economies as explained in table 28,29,30 &31, respectively attached in the appendix. Furthermore, we have conducted comprehensive analysis of selected cities of Pakistan by following the (WasteAware Benchmark Indicators) as discussed in the following section.

Component 1: Public Health – Waste Collection: Public health indicators illustrate clear provincial disparities. Punjab performs strongest, with cities such as Lahore (80%), Faisalabad (75%), Rawalpindi (70%), Gujranwala (70%), Multan (73%), and Sahiwal (75%) demonstrating robust waste-collection coverage (Urban Unit, 2025). Waste captured by the system also remains comparatively high in Punjab (60–77%). In contrast, Peshawar (47%), Karachi (55%), Quetta (61%), and Muzaffarabad (70%) show weaker performance due to fleet shortages, shortage of human resources, and operational inefficiencies (Urban Unit, 2025).

Component 2: Environmental Control – Treatment and Disposal: Environmental control indicators reveal a mixed performance. Punjab again leads with controlled disposal scores between 50–65%, supported by controlled dumpsite protocols set by the waste management companies to manage dumpsites in a controlled manner like provision of soil cover on daily basis, installation of way bridge to monitor daily tonnage of the waste at dumpsite and plantation drives. Environmental protection scores, however, remain low nationwide, typically 24–45%, reflecting poor leachate control, inadequate engineered landfills, and limited emissions monitoring (Saif et al., 2015). Punjab shows better adherence due to contractor oversight, but overall performance still reveals gaps. However, recognition of informal sector is missing nation-wide who are segregation around 10-20% of the generated waste before coming to the disposal points and playing their role in circular economy in informal way (Nawaz et al., 2021) . There is need to formalize them in a parasitic relationship. Detailed analysis is depicted at Fig. 1.

Component 3: Resource Recovery – Reduce, Reuse, and Recycle: Resource recovery is the weakest component. Recycling rates remain low—mostly 10–30% reflecting minimal segregation at source, limited MRFs, and inadequate policy incentives (Erfani et al., 2018). Punjab performs slightly better due to awareness campaigns and pilot user-fee collection, which encourages waste minimization. However, even in Punjab, 3R quality scores remain below 20%, aligned with national challenges due unavailability of any policies, laws, and regulations on Extender Producer Responsibility (EPR) and source segregation nation-wide (Aslam, 2020). Detailed analysis is depicted at Fig. 1.

Component 4: Governance: Governance indicators show moderate inclusivity (40–70%) but weak institutional capacity in many provinces. Punjab demonstrates relatively better alignment, but national SWM framework scores remain low (13–25%) except Karachi (71%) because of availability of their regulation at solid waste management handling (Mahmood & Khan, 2019). Moreover, all SWM companies/ boards have adequate budgets but financial sustainability model is very weak due to the absence of cost-recovery mechanisms. Detailed analysis according of 'WasteAware' benchmark indicators for integrated sustainable waste management in cities (Wilson et al., 2015) is depicted in Fig. 1.

Figure 1. Sectoral Analysis at National Level – Waste Aware Indictors

No.	Category	Indicators	Results										
	Province		Punjab						KPK	Sindh	Balochistan	AJK	Fedral
			Lahore	Faislabad	Rawalpindi	Gujrawala	Multan	Sahiwal	Peshawar	Karachi	Quetta	Muzzafrabad	Islamabad
Background Information													
B1	Country Level Income	World Bank Income Category	Lower Middle Income										
		GNI per Capita	$1,430 per person										
B2	Population	Total Population of the District (million, 2025)	13.349	9.572	6.37	6.32	5.6	3.01	4.91	22.1	2.71	0.761	2.49
B3	Waste Generation	MSW generation (tonnes/day)	7209	3663	2456	2431	2150	1161	1891	12956	1249	194	1149
		MSW generation (tonnes/year)	2631285	1336995	896440	887315	784750	423765	690215	4728940	455885	70810	419385
Key Waste Related Data													
W1	Waste per Capita	MSW per capita -Urban (kg/day)	0.54 Kg/cap/day	0.45 Kg/cap/day					0.45 kg/cap/day	0.6 kg/cap/day	0.5 kg/cap/day	0.255 kg/cap/day	0.5 kg/cap/day
		MSW per capita - Rural (kg/year)	0.32 kg/cap/day						0.32 kg/cap/day	0.4 kg/cap/day	0.42 kg/cap/day	0.255 kg/cap/day	0.42 kg/cap/day
W2	Waste Composition:												
W2.1	Organics	Organic (food & green waste)	49.42	61.7	52.83	50.34	52.03	61.16	58.76	57.8	32.93	62	55.28
W2.2	Paper	paper & cardboard	0.42	1.16	2.19	2.74	1.23	1.1	1.57	2.19	3.57	5	3.45
W2.3	Plastics	Plastics	15.25	13.16	11.02	12.29	7.37	17.84	12.13	11.87	14.99	13	1.27
W2.4	Metals	Metals	0.06	0.14	0.38	0.31	0.19	0.04	0.01	0	0.288	0	0.22
Physical Components: 4 key fractions - as % of total waste generation													
1.1	Public health - waste collection	Waste collection coverage (%)	80	75	70	70	73	75	47	55	61	70	55
1.2		Waste captured by the system	77	60	67	65	68	70	43	45	56	65	45
IC		Quality-waste collection service	75	60	65	50	55	67	40	40	50	55	45
2	Environmental control - waste treatment & disposal	Controlled treatment & disposal	63	50	55	53	58	65	45	60	60	50	45
2E		Env. protection of treatment & disposal	60	40	45	43	43	25	24	33	25	25	25
3	Reduce, reuse & recycle	Recycling rate	30	15	11	15	13	30	11	26	18	15	20
3R		Quality of 3Rs	21	20	10	10	10	8	8	13	8	10	10
Governance Factor													
4U	Inclusivity	User inclusivity	70	60	65	60	60	60	47	40	29	40	50
4P		Provider inclusivity	30	18	18	20	15	20	15	50	20	15	30
5F	Financial sustainability	Financial sustainability	70	60	65	65	60	57	55	70	40	60	75
6N	Sound institution, proactive policies	Adequacy of national SWM framework	21	13	21	17	17	20	25	71	17	15	60
6L		Local institutional coherence	80	74	77	74	75	75	75	88	38	40	65

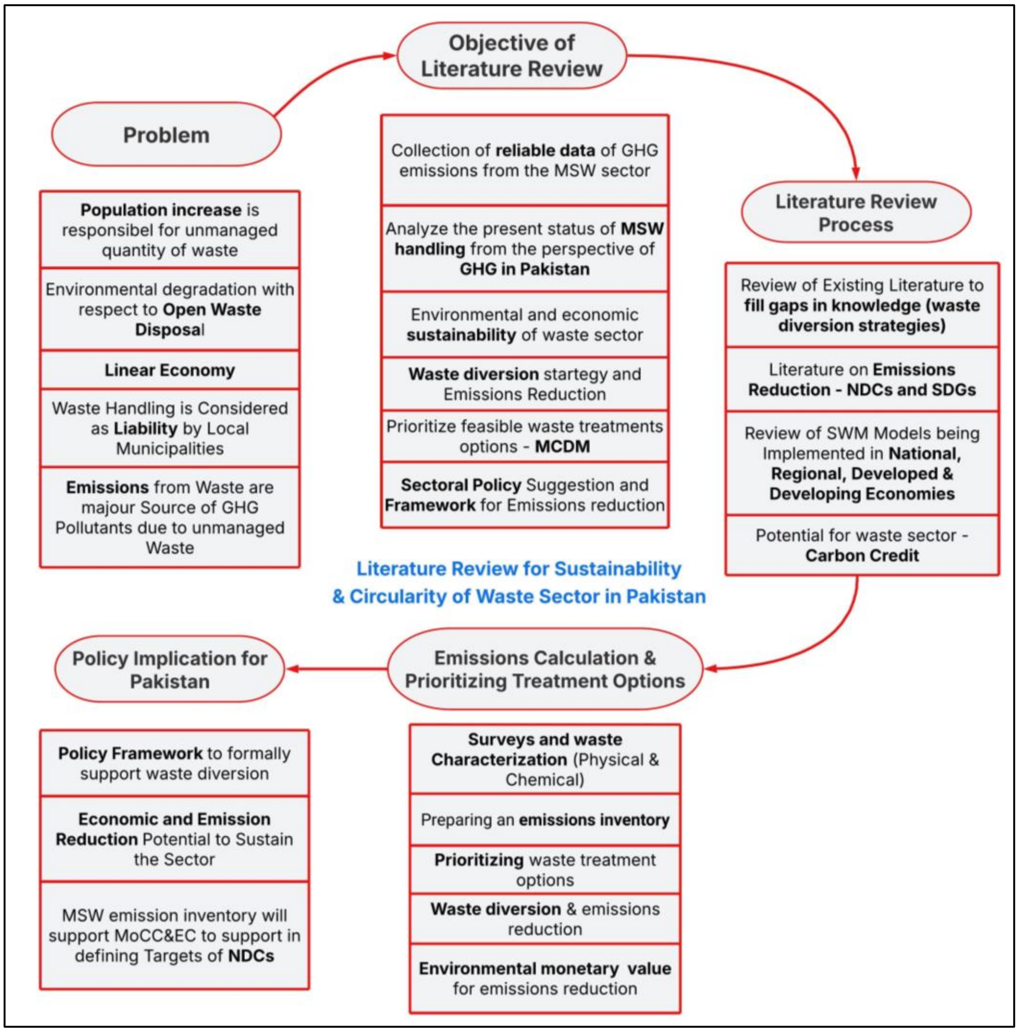
Key for Colour Coding		Key for abbreviations:	
(green)	High: score in the rang 81% - 100%	B – Background Data	4U – User Inclusivity
(light orange)	Medium-High: score in the rang 61-80%	W – Waste Data	4P – Provider Inclusivity
(orange)	Medium: score in the rang 41-60%	1C – Public Health	5F – Financial Sustainability
(yellow)	Low-Medium: score in the rang 21-40%	2E – Environmental Control	6N – National Framework
(red)	Low : score in the range 0-20%	3R– Resource Management	6L – Local Institutions

Source: Wilson et al. (2015).

2.9. Takeaways from Literature Review

The main objective of the literature review was to collect data on waste composition and related emissions, and to analyze current waste management practices including strategies in the country, region, and both developing and developed economies. This approach also supports identifying sectoral gaps in Pakistan and highlights best practices to fill identified gaps. This section paves the way towards pinpointing the importance of the emissions inventory and policy framework to sustain the local waste sector. This entire process, including the problem statement, objective, and process for the literature review, the need for an emissions calculation, prioritization of treatment options, and policy implications, is explained in Fig. 2.

Figure 2. Literature Review Process and Takeaways for Pakistan



Source: Authors' compilations.

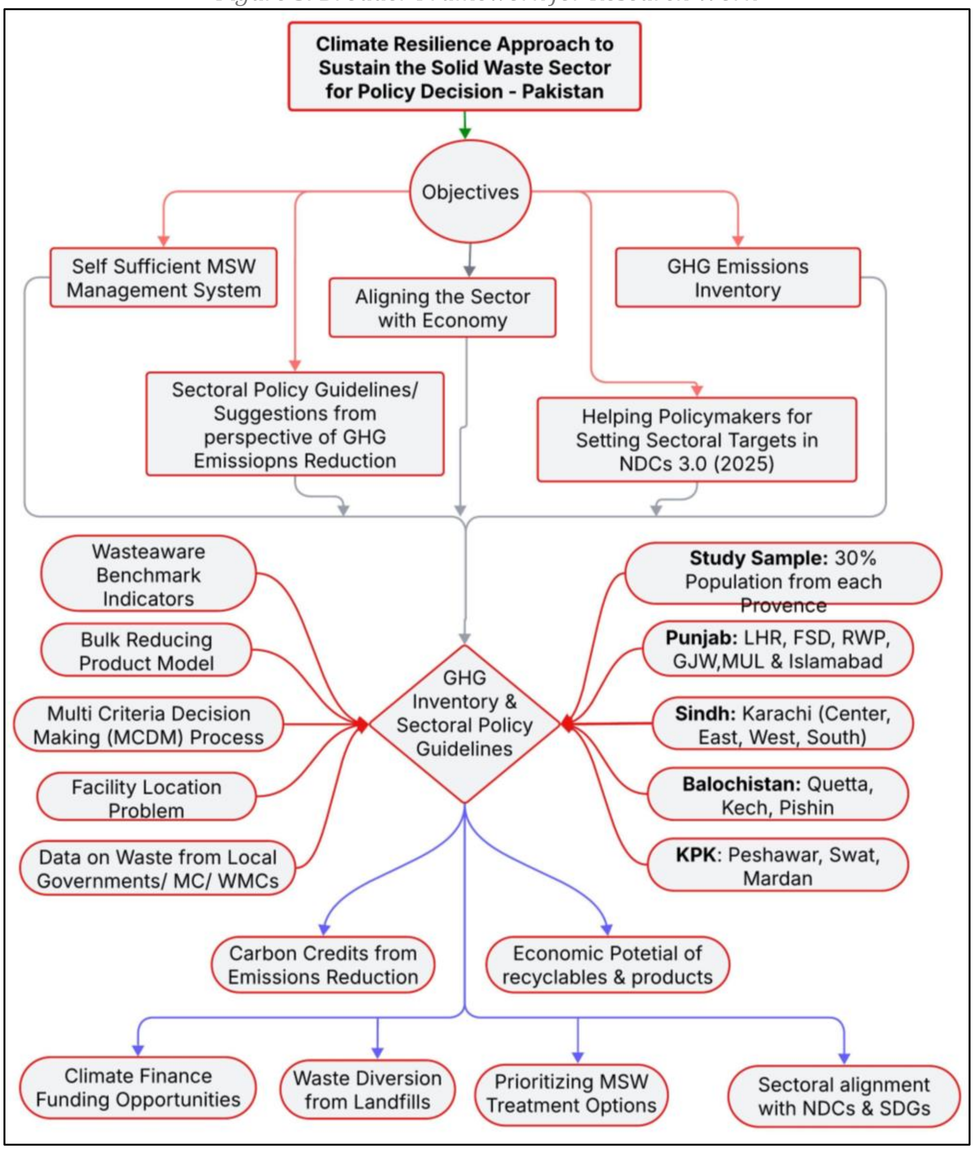
This research work, including emissions inventory, emissions reduction strategies with opportunities for carbon credit and funding, and highlights for sectoral policy framework, will facilitate policymakers to develop waste sector policy for the sustainability and integration with CE, as explained in Table 32 attached in the appendix.

MATERIALS AND METHODS

3.1. Research Framework and Area

This research work, including GHG emissions calculations, emissions reduction strategies with opportunities for carbon credit and funding, and highlights for sectoral strategy framework, will facilitate policymakers to develop waste sector policy for the sustainability and integration with CE, as explained in Table 32 attached in the appendix.

Figure 3. Broader Framework for Research Work



Source: Authors' compilations.

3.2. Research Population and Sample Size

We have selected about all major cities of Punjab including provincial headquarters of other provinces to perform our study. The population of selected districts is 77.5 million as per year 2025 based on population census 2023 report (Hussain & Hassan, 2024), which is about 30% of total population (258.6 million) of Pakistan. The detail of sample size to perform this research work is depicted in Table 4.

Table 4. Population Sample Size for Research

Districts	Population 2025 (projected)
Punjab Districts	
Lahore	13,702,587
Faisalabad	9,513,712
Rawalpindi	6,379,008
Gujranwala	6,315,330
Multan	5,585,594
Sahiwal	3,016.778
Sindh	
Karachi (all districts)	22,103,723
Khyber Pakhtunkhwa (KPK) Districts	
Peshawar	4,910,599
Baluchistan	
Quetta	2,714,591
Azad Jammu & Kashmir (AJK)	
Muzaffarabad	761,268
Federal Capital	
Islamabad	2,498,283
Total Sample Population (30%)	**77,501,478**

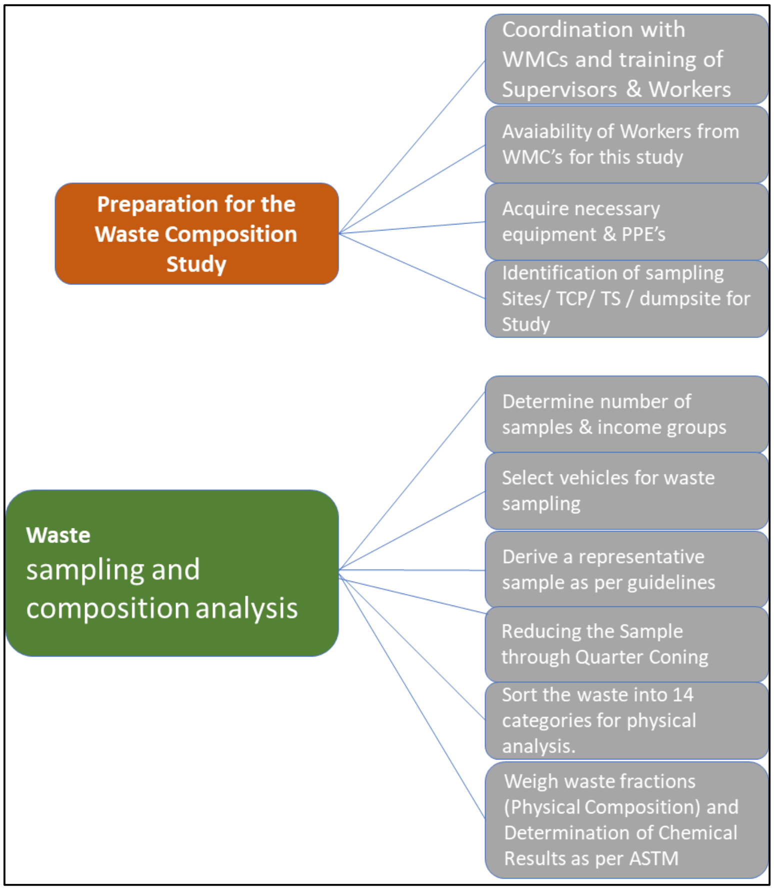
Source: GOP 2023.

However, we have included the **whole Punjab** in this study due to availability of latest data (2024) on sectoral asset mapping at the Urban Unit (Urban Unit, 2025) We further conducted this research work in three phases to achieve the objectives. Details of these phases are explained as follows:

3.3. Research Phase-I: Waste Characterization Study

The Waste Wise Cities Tool (WaCT) module 3.3, step 6, uses the Quarter Conning Method to collect representative municipal solid waste (MSW) samples at the dumpsite (UN-Habitat, 2021). This manual technique helps reduce bias and ensures accurate waste composition data, even in mixed waste. For the study, samples were collected from low, middle, and high-income areas, sorted by hand into 14 categories by following Quarter Conning technique. Sample locations were chosen with input from Waste Management Companies (WMCs). The scheme of study preparation and waste sampling steps and details are presented in the Fig. 4.

Figure 4. Waste Wise Cities – Scheme for Study and Waste Sampling



Source: UN-Habitat (2021).

Waste samples were collected from vehicles visiting solid waste transfer stations. Apparatus used for physical composition (Fig. 5) of the study includes;

- Electrical weighing scale with capacity of 100 kg
- Tarps, shovels, and hand broom
- First Aid Kit
- Gloves for workers to perform sorting task and
- Surgical suits

Figure 5. Apparatus for Characterization Study

Source: Author's computations.

We have performed 39 physical waste characteristics samples (Fig. 6), including 12 from Punjab (Lahore, Sahiwal, Multan, Faisalabad, Gujranwala, Rawalpindi), 6 from Peshawar, 9 from Karachi, 3 from Quetta, 2 from Muzaffarabad, and 7 from Islamabad. Waste from vehicles was emptied and mixed, then sampled using shovels to ensure a representative 70-100 kg batch through quarter quoining technique. Each sample was sorted by hand into 14 categories (EPA, 2024), weighed, and the average composition calculated as explained in Table 5.

Table 5. Waste Characterization Components

Components		**Explanation**
1	Combustibles	Combustible waste which are undefined in other categories
2	Diaper	Baby diapers and sanitary pads
3	Elec.-Electronic Waste	Every type of elec. And electronic wastes.
4	Glass	Every type of glasses
5	Hazardous W	Accumulator, battery, medical waste etc.
6	Biodegradable W	Food waste, fruits, vegetables etc.
7	Metals	All kind of metals
8	Non-Combustibles	Stone, demolition waste, bond, curbside
9	Paper-Cardboard	Newspaper, magazines, office papers etc.
10	Pet	Water bottles
11	Nylon	Shopping bags
12	Plastics	All kind of plastics except pet
13	Tetrapak	Milk and juice cardboard
14	Textile	All kind of textile wastes

Source: EPA (2024).

Five kg laboratory samples were placed inside sample bags and labeled by writing the corresponding waste code on them for carrying out laboratory analysis, i.e., proximity and ultimate analysis, only for "Punjab cities" against parameters as explained in Table 33 attached in appendix.

Figure 6. Planning and sampling for Waste Characterization

Source: Author's computations.

3.4. Research Phase-II: GHG Emissions Calculations and Scenarios Development

The total GHG emissions was calculated from each waste collection, transportation and disposal under the guidelines of International Panel on Climate Change (IPCC) by using Institute for Global Environment Strategy (IGES) Emissions Quantification Tool (EQT) - Version III calculator. The Short-Lived Climate Pollutants (SLCP) of the waste sector are also estimated by use of an EQT which calculates GHG/ SLCP of the waste sector based on country-specific emission factors and IPCC recommended default values as formulated by the IGES, Japan (Bengtsson & Menikpura, 2013), in accordance with the lifecycle assessment (LCA) method of considering the actual and projected emissions of the waste sector. In addition, scenarios that implied the following assumptions were: 100 percent use of compost materials as farm inputs, use of heat and biogas as an alternative to coal and natural gas, retrieval of compost materials as an anaerobic digestion (AD) by-product, use of compost material as a by-product of mechanical biological treatment (MBT) process, use of compost material as a substitute to chemical fertilizer, continuous stoker type incineration, operation based on the use of diesel, sanitary landfilling (25 years life) with recovery of landfill gas (Bengtsson & Menikpura, 2013) . The tool incorporates the IPCC Tier 2 methodology and enables more specific emissions estimates through the use of country specific data about waste generation, management practices, and composition. Net climate impact displayed in terms of CO_2 equivalent values per ton of waste. The global warming potential (GWP) of BC has yet to be officially determined; therefore, the net BC emissions are estimated and presented separately in EQT-III by IGES Japan. The view of EQT for estimation of the GHGs/ SLCPs from Solid Waste Sector – Version-III (IGES, 2025) is depicted at Fig. 7.

Figure 7. EQT version-III Calculator for Solid Waste Emissions Calculation

Source: IGES (2025).

Scenarios are developed based on waste diversion and related emissions modeling is performed for local waste sector to estimate the sector global warming impact from waste collection, transportation, open burning, and disposal under BAU. For emissions reduction potential, we calculated the net emissions by proposing scenarios on waste diversion at 20%, 40%, 60% and 80% for MSW treatment options as explained in Table 6. From emissions perceptive, we use the unit values of kg per ton, tons per month, and tons per year for BC emissions, however GHG emissions are calculated in unit values of CO2-eq-per ton, tons of CO2-eq. per month, and tons of CO2-eq-per year.

Table 6. Waste Calculation of GHG Emissions

SN	GHG Emission estimates for Business as Usual (BAU) Scenario	Scenarios Development for GHG emission Reduction – Technology for Decision-Making
1	Transportation of solid waste	Compost
2	Mix waste landfilling	Anaerobic Digestion
3	Open burning of waste	Refuse Derived Fuel
4	-	Recycling
5	-	Mechanical Biological Treatment
6	-	Incineration
7	-	Landfill with Gas Recovery

Source: Author's computations.

The relevant necessary district wise data used for emissions calculation such as population, waste generation rate, daily waste generation (t/d), daily waste collected (t/d), fuel consumption in liters per ton (l/t), daily fuel consumption in liter per day (l/d), daily diesel consumption (l/d), daily gasoline consumption (l/d), daily diesel consumption at temporary collection point (TCP) in liter per day (l/d), daily energy consumption at TCP (kWh/d), daily diesel consumption at LFS in liters per day (l/d), and daily energy consumption at LFS (Kwh/d) is collected from Punjab (Table 34), Sindh (Table 35), KPK (Table 36), Baluchistan (Table 37), AJK (Table 38), and Islamabad is depicted at Table 39 attached in appendix.

3.5. Research Phase-III: Economic Potential of Waste Sector

To determine the economic potential of the waste sector, we have employed economic modeling equations "1 to 7" from research work (Iqbal et al., 2022b).

3.6. Research Phase-IV: Prioritizing MSW Treatment Options and Policy Highlights

The MCDM approach such as AHP method is applied for the ranking of feasible waste treatment options for Pakistan. The main objective of AHP is to prioritize the MSW treatment options based on defined criteria and alternatives. We have defined ten (10) criteria to run AHP, which detail is as follows;

I. Upfront investment cost to establish the facility
II. Operational cost of the facility
III. Land requirement to establish the facility
IV. Energy requirement to run the facility
V. Emissions reduction potential
VI. Carbon credit potential
VII. Market sale potential
VIII. Sound/ proven technology for MSW treatment
IX. Environmental mitigation cost/ method
X. Technology/ facility's coherence with the local MSW composition

Furthermore, we have also proposed seven (7) available alternative MSW treatment options to run the AHP model. Detail of alternative options for MSW treatment are as follows;

I. Compost
II. Anaerobic Digestion (AD)
III. Recycling/ recovery of recyclables
IV. Incineration
V. Refuse Derived Fuel (RDF)
VI. Mechanical Biological Treatment (MBT)
VII. Landfilling with Landfill Gas (LFG) recovery

We also assess the sectoral gaps and proposed policy guidelines to overcome these gaps.

RESULTS AND DISCUSSION

4.1. Physical Waste Characteristics Results at National Level

The waste characterization study was conducted in selected cities of Pakistan to assess the governing waste components at national level. The results of the waste characterization indicate that there is a high difference in the MSW composition within Punjab, Islamabad (capital territory), Azad Jammu and Kashmir (AJK), Sindh, Baluchistan and Khyber Pakhtunkhwa (KPK), which is indicative of disparities in the consumption patterns, socioeconomic statuses, waste management practices, and role of informal waste sector across different geographic areas of the country. The average MSW physical composition at national level reflects that biodegradable or kitchen waste is governing factor; on average, the organic waste constituted approximately 53.98% of the total MSW generated in Pakistan, depending on the locality and socioeconomic conditions of the area. The organic waste stream was largely composed of food waste, green waste (such as kitchen waste, fruit and vegetable markets residue, and garden trimmings), and other biodegradable materials. The high proportion of organic waste has direct implications for environmental sustainability, particularly in terms of greenhouse gas (GHG) emissions. Other waste components include plastic (all types) at 11.55%, diaper waste at 9.08%, non-combustible at 8.98%, textile at 5.58%, combustible 3.62, paper/ cardboard at 2.89%, nylon at 2.15%, glass at 1.24%, Tetrapak at 0.45%, pet waste at 0.17%, hazardous waste at 0.16%, metals at 0.12%, and electronic waste at 0.05% as depicted in Table 7 and Fig. 8.

4.2. Physical Waste Characteristics Results at Provincial Levels

Punjab MSW Composition: This study conducted across selected urban centers in Punjab revealed that the predominant component of Municipal Solid Waste (MSW) is the organic fraction. Average physical composition of municipal solid waste across Punjab reveals that biodegradable waste forms the largest fraction, constituting 54.09% of the total waste. Plastics also form a significant portion at 13.42%, followed by diapers at 12.33%, reflecting substantial use of single-use and sanitary products. Textiles constitute 6.61%, and non-combustibles make up 4.03%. Combustibles are relatively low at 3.41%, while paper and cardboard contribute 1.48%. Minor fractions include glass (1.4%), Tetrapak (1.25%), nylon (0.61%), PET (0.75%), metals (0.21%), electronic waste (0.22%), and hazardous waste (0.2%). Details analysis of results is depicted in Table 7.

Islamabad MSW Composition: Islamabad shows a high share of biodegradable waste (55.08%), similar to Punjab, but exhibits unusually elevated quantities of nylon at 12.26% and diapers at 13.03%, making these significant contributors. Plastics remain present at 0.99%, which is comparatively low. Combustibles are 4.48%, paper-cardboard is 3.45%, and glass stands at 1.66%. Minor components include non-combustibles (1.42%), metals (0.22%), PET (0.28%), Tetrapak (1.43%), electronic waste (0.06%), and hazardous waste (0.77%), the latter being notably higher than in most provinces as depicted in Table 7.

Sindh MSW Composition: The waste profile of Sindh is dominated by biodegradable waste at 59.7%, followed by plastics at 13.7%, diapers at 11.8%, and textiles at 6.4%. Combustibles contribute 2.8%, non-combustibles 2.9%, and paper-cardboard 1.9%. Glass makes up 0.8%, while metals, PET, nylon, Tetrapak, electronic waste, and hazardous waste show no measurable quantities, indicating either negligible presence or reporting gaps as depicted in Table 7.

KPK MSW Composition: KPK's waste stream is dominated by biodegradable waste (60.1%), consistent with other provinces. Plastics make up 13.2%, diapers account for 9.3%, and non-combustibles contribute 7.1%. Textiles represent 5.7%, while combustibles are at 2.1%. Minor fractions include paper-cardboard (1.9%), and glass (0.6%), with no metals as depicted in Table 7.

Baluchistan MSW Composition: Baluchistan displays a very distinct waste composition profile, driven mainly by an exceptionally high proportion of non-combustibles at 34.4%, the highest among all regions—likely due to construction debris, soil, stones, and inert materials. Biodegradable waste is relatively low at 32.9% compared to other provinces. Plastics constitute 15%, making them a prominent waste type, followed by textiles at 6.9%. Combustibles appear at 4.9%, paper-cardboard at 3.6%, and glass at 2%. Diapers, PET, nylon, Tetrapak, metals, electronic waste, and hazardous waste all show 0%, indicating limited presence or unrecorded data at Table 7.

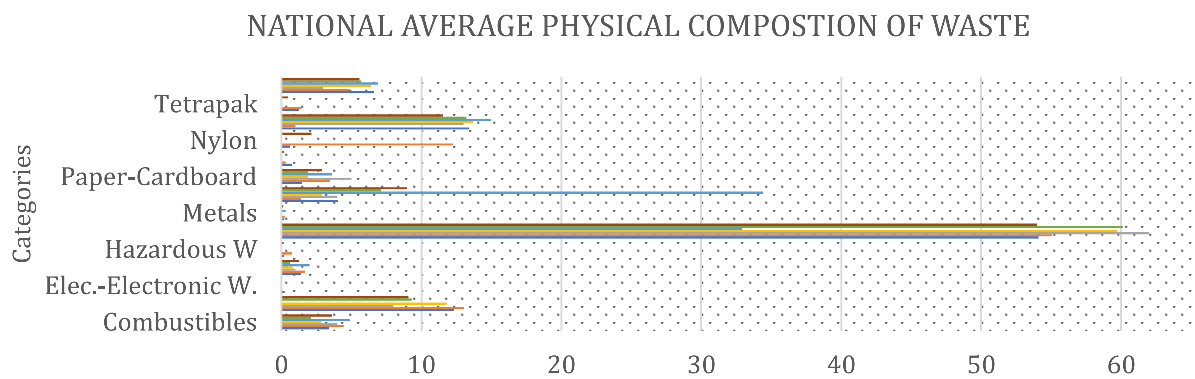
AJK MSW Composition: AJK has the highest biodegradable waste share at 62%, reflecting the region's organic waste–dominated generation pattern, likely due to rural characteristics and lower industrialization. Plastics contribute 13%, while diapers make up 8%. Combustibles and non-combustibles are each 4%, and textiles account for 3%. Paper-cardboard forms 5%, showing relatively higher recycling-related material presence. There is no recorded presence of hazardous waste, electronic waste, PET, nylon, Tetrapak, metals, or glass as depicted in Table 7.

Table 7. Physical Waste Composition (%) at National Level

Components	**Punjab (%)**	**Islamabad (%)**	**AJK (%)**	**Sindh (%)**	**Baluchistan (%)**	**KPK (%)**	**National (%) Average**
Combustibles	3.41	4.48	4.0	2.8	4.9	2.1	**3.62**
Diaper	12.33	13.03	8.0	11.8	0.0	9.3	**9.08**
Elec.-Electronic W.	0.22	0.06	0.0	0.0	0.0	0.0	**0.05**
Glass	1.4	1.66	1.0	0.8	2	0.6	**1.24**
Hazardous W	0.2	0.77	0.0	0.0	0.0	0.0	**0.16**
Biodegradable W.	54.09	55.08	62.0	59.7	32.9	60.1	**53.98**
Metals	0.21	0.22	0.0	0.0	0.3	0.0	**0.12**
Non-Combustibles	4.03	1.42	4.0	2.9	34.4	7.1	**8.98**
Paper-Cardboard	1.48	3.45	5.0	1.9	3.6	1.9	**2.89**
Pet	0.75	0.28	0.0	0.0	0.0	0.0	**0.17**
Nylon	0.61	12.26	0.0	0.0	0.0	0.0	**2.15**
Plastics	13.42	0.99	13.0	13.7	15	13.2	**11.55**
Tetrapak	1.25	1.43	0.0	0.0	0.0	0.0	**0.45**
Textile	6.61	4.87	3.0	6.4	6.9	5.7	**5.58**
Total	100	100	100	100	100	100	**100.00**

Source: Data Collected during this study working/surveys.

Figure 8. Physical MSW Characteristics at National Level



	Combustibles	Diaper	Elec.-Electronic W.	Glass	Hazardous W	Biodegradable W.	Metals	Non-Combustibles	Paper-Cardboard	Pet	Nylon	Plastics	Tetrapak
National % Average	3.62	9.08	0.05	1.24	0.16	53.98	0.12	8.98	2.89	0.17	2.15	11.55	0.45
KPK	2.1	9.3	0.0	0.6	0.0	60.1	0.0	7.1	1.9	0.0	0.0	13.2	0.0
Balochistan	4.9	0.0	0.0	2	0.0	32.9	0.3	34.4	3.6	0.0	0.0	15	0.0
Sindh	2.8	11.8	0.0	0.8	0.0	59.7	0.0	2.9	1.9	0.0	0.0	13.7	0.0
AJK	4.0	8.0	0.0	1.0	0.0	62.0	0.0	4.0	5.0	0.0	0.0	13.0	0.0
Islamabad	4.48	13.03	0.06	1.66	0.77	55.08	0.22	1.42	3.45	0.28	12.26	0.99	1.43
Punjab	3.41	12.33	0.22	1.4	0.2	54.09	0.21	4.03	1.48	0.75	0.61	13.42	1.25

Source: Data Collected during this study working/surveys.

4.3. Chemical Composition Results of Selected Cities

The chemical characterization of waste across Faisalabad, Gujranwala, Lahore, Sahiwal, Rawalpindi, Islamabad, Multan, and Quetta shows noticeable differences in moisture content, calorific value, and major fuel-related properties (high calorific value waste). Overall, the results indicate that municipal solid waste (MSW) in most cities contains high amounts of moisture and ash, which generally lowers its energy potential. The average moisture content, Gross Calorific Value (GCV), and ash content for the selected cities are reported at 50.6%, 3414.4%, and 21.2%, respectively. The overall average chemical characteristics of MSW (Urban Unit, 2025) are depicted in Table 8.

Table 8. Chemcial Analysis Results (avg. values) of MSW at National Level

SN	Parameters	Methods	Average %
1	Moisture, Total %	Based on ASTM D3302	50.6
2	Moisture, Laboratory Sample %	Based on ASTM D3173	4.0
3	Ash %	Based on ASTM D3174	21.2
4	Volatile Matter %	Based on ASTM D3175	49.5
5	Fixed Carbon by Calculation %	Based on ASTM D3172	10.0
6	Sulfur %	Based on ASTM D4239 Method A	0.2
7	Gross Calorific Value kcal/kg	Based on ASTM D5865	3,414.4
8	Net CV @ Constant Pressure kcal/kg	Based on ASTM D5865	2,813.9

9	Oxygen (by difference) %	Based on ASTM D31761	19.6
10	Carbon %	Based on ASTM D5373	31.7
11	Hydrogen %	Based on ASTM D5373	5.0
12	Nitrogen %	Based on ASTM D5373	0.8

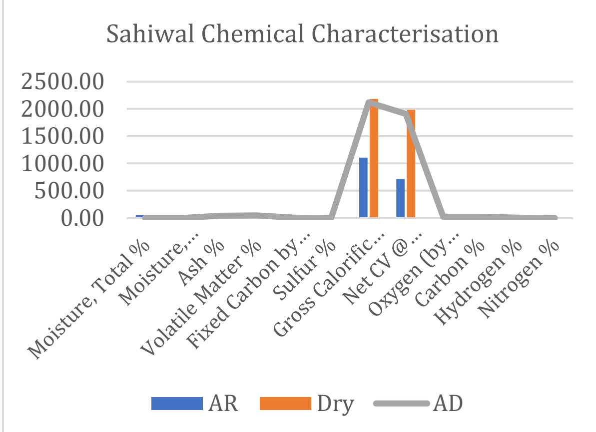
Source: Urban Unit (2025).

The MSW composition at the national level shows high moisture contents at 50.6%, significant ash content at 21.2%, and moderate calorific value ≈3414 kcal/ kg, indicating a mix of wet organics and inert materials. However, based on the chemical composition of MSW at the national level, a phased approach that combines separation, biological treatment, low-tech MRFs, bio-drying, and cement co-processing is the most practical and financially viable strategy for improving MSW management in resource-constrained environments of Pakistan, as explained in Table 42 in appendix.

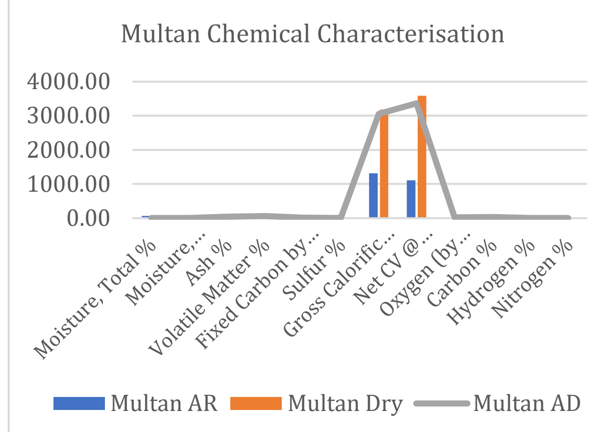
In Punjab, Faisalabad (Table 43) and Gujranwala (Table 44) both shows very high moisture contents in waste samples; in the as-received (AR) state, at 57.5% and 65.3% respectively, while Lahore has the highest recorded AR moisture (78.15%) as depicted in Table 45. Sahiwal and Multan also have high moisture, above 49% and 58%, as explained in Table 46 & 47. While Rawalpindi shows significantly lower moisture (23.5%) as explained at Table 48, making its waste comparatively drier. Quetta's moisture is also moderate (26.67%) as explained in Table 49. Ash content varies across cities, but most show moderate to high levels. Lahore and Faisalabad have ash around 20–27% (dry basis), while Gujranwala, Sahiwal, and Multan show even higher ash percentages, above 35–43%, indicating a considerable presence of inert material. Rawalpindi has relatively lower ash (19.2% dry), while Quetta reports 15.4%, suggesting cleaner combustible waste. Volatile matter is high in all cities, reflecting the presence of easily combustible organic components. Lahore and Rawalpindi show the highest proportions (around 65–69% dry). Faisalabad, Gujranwala, Multan, and Sahiwal also report strong volatile fractions (around 47–63%), while Quetta has an exceptionally high 71.43%, indicating significant burnable material. Calorific values vary notably. Rawalpindi shows the highest energy potential with a gross CV of 4537 kcal/kg (AR), followed by Multan (1310 kcal/kg) and Faisalabad (1754 kcal/kg). Lahore and Gujranwala have relatively low AR calorific values (close to 1070 kcal/kg), mainly due to high moisture. Quetta's calorific value, measured in BTU (5399.6 BTU ≈ 1350 kcal/kg), falls in the moderate range. Carbon content is highest in Rawalpindi (44.7% AR), followed by Multan and Faisalabad (around 14–16% AR). Sulfur levels remain low across all cities. Graphical representation is explained at Fig.9.

Overall, the data shows that waste in most cities has limited energy recovery potential due to very high moisture and ash, except Rawalpindi and Quetta, which show comparatively better fuel properties.

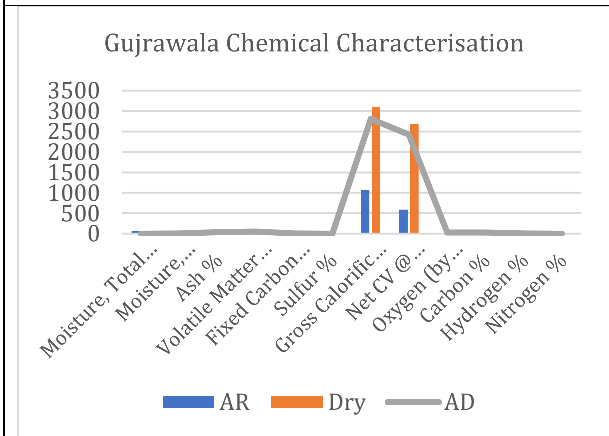
Figure 9. Graphical Representation of MSW Chemical Composition



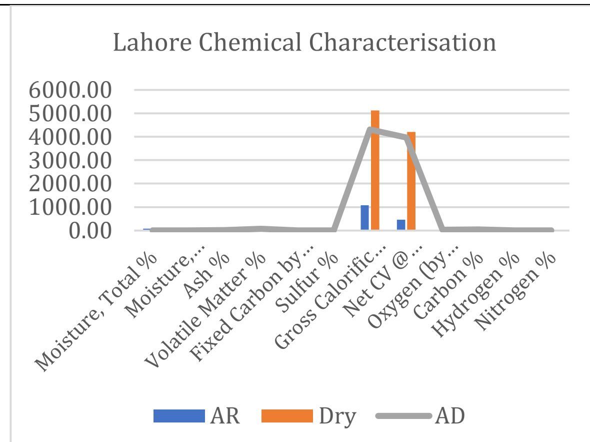
Sahiwal Chemical Waste Characterization Results



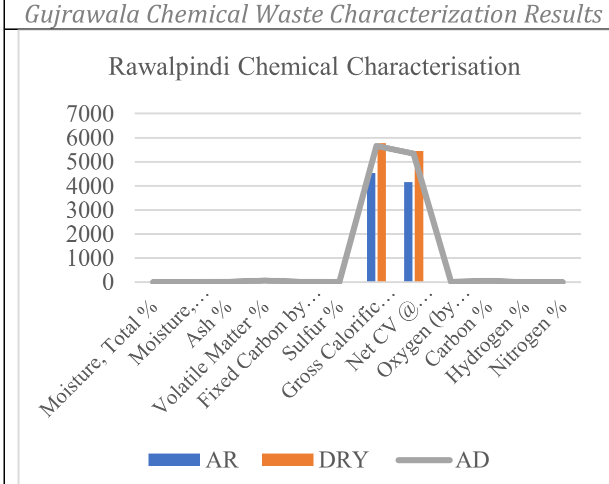
Multan Chemical Waste Characterization Results



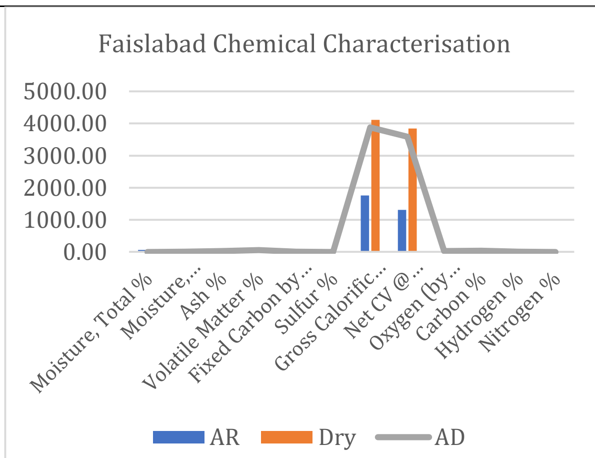
Gujrawala Chemical Waste Characterization Results



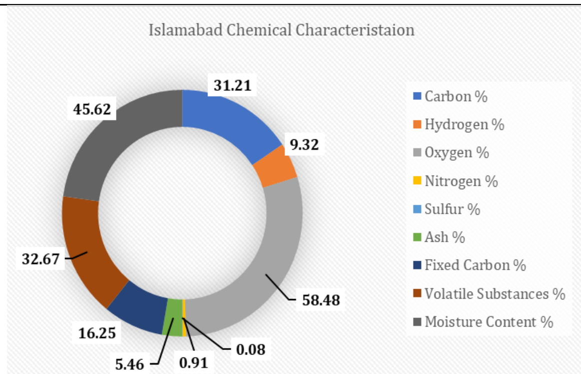
Lahore Chemical Waste Characterization Results



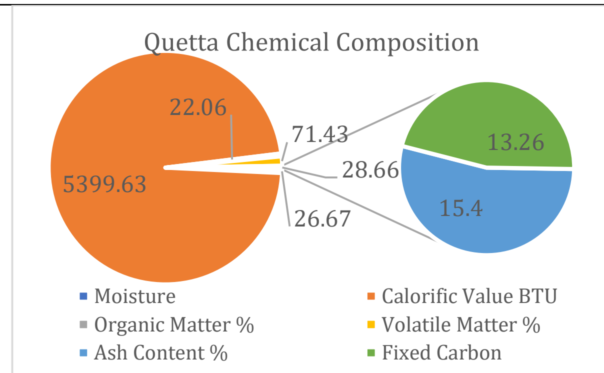
Rawalpindi Chemical Waste Characterization Results



Faisalabad Chemical Waste Characterization Results



Islamabad Chemical Waste Characterization Results



Quetta Chemical Waste Characterization Results

Source: Urban Unit (2025).

4.4. Emissions Calculation (BAU) from MSW in Pakistan

In Table 9, it is shown that the collective climate impact from all over Pakistan in terms of generated and collected waste is around **26.5 Million tons of CO2-eq** and**18.5 Million tons of CO2-eq,** respectively. Black carbon in terms of generated and collected waste is around **1034.9 tons** and 722 tons per yearly, respectively. Heat maps of Pakistan for sector's GHG and BC emissions from generated waste are depicted at Fig. 10.

Table 9. Collective Summary of Emissions

Province	**Emissions per tonne of generated waste**		**Emissions per tonne of collected waste**		**Emissions from yearly generated waste**		**Emissions from yearly collected waste**	
	BC	**GHG**	**BC**	**GHG**	**BC**	**GHG**	**BC**	**GHG**
	kg/ ton	**kg of CO_2-eq./ ton**	**kg/ ton**	**kg of CO_2-eq./ ton**	**Tons**	**Tons of CO_2-eq.**	**Tons**	**Tons of CO_2-eq.**
Punjab	0.023	930.3	0.024	1051.0	473.2	16,025,062	378.02	13,407,509
Sindh	0.021	529.8	0.023	561.6	222.1	5,650,345	126.68	3,269,770
Baluchistan	0.035	320.6	0.067	328.7	95.3	808,526	64.79	316,086
KpK	0.033	582.5	0.068	602.9	208.2	3,476,329	131.69	1,162,116
Capital	0.070	618.0	0.074	504.9	29.2	259,169	16.432	112,774
AJK	0.015	578.1	0.015	593.7	6.9	275,573	5.07	198,077
Total Impact	0.033	593.2	0.045	607.1	**1,034**	**26,495,007**	**722**	**18,466,335**

Source: Authors' calculations based on IGES (2025).

Greenhouse Gas Emission Inventory of Punjab: The Greenhouse gas emission inventory of Punjab (Urban Unit, 2025) is given in table 50 attached in the appendix, which shows a huge quantum of greenhouse gas emissions and their climate impact from yearly generated and collected waste i.e., around **16 Million tons of CO_2-eq,** and in **13.4 Million tons of CO_2-eq**, respectively under the BAU Scenario.

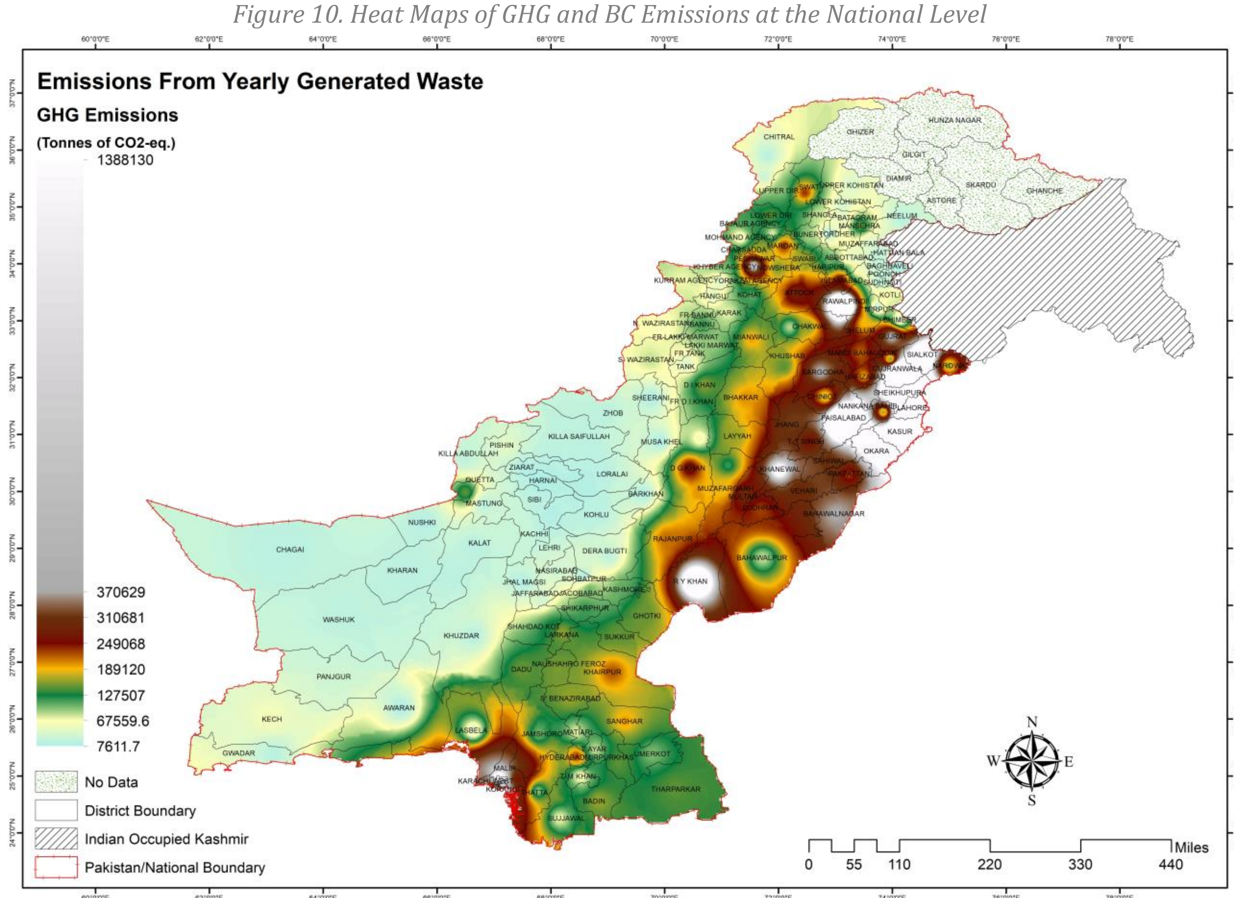
Greenhouse Gas Emission Inventory of Sindh: The Estimated Greenhouse gas emission inventory of Sindh is given in Table 51 attached in the appendix, which shows a huge quantum of greenhouse gas emissions and their climate impact from yearly generated and collected waste, i.e., around **5.7 Million tons of CO_2-eq,** and in **3.3 Million tons of CO_2-eq**, respectively in the BAU Scenario.

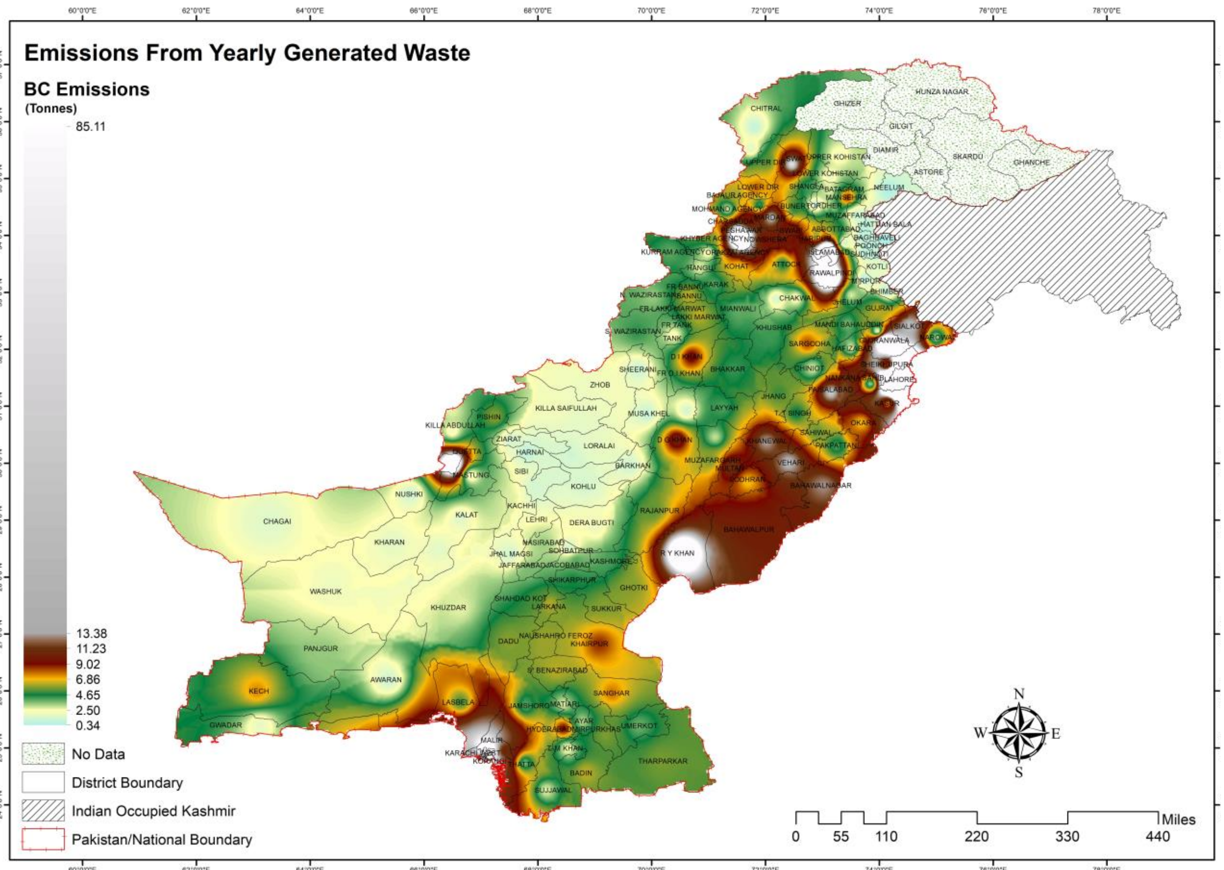
Greenhouse Gas Emission Inventory of Khyber-Pakhtunkhwa: The Estimated Greenhouse gas emission inventory of Khyber-Pakhtunkhwa is given in Table 52 attached in the appendix, which shows a huge quantum of greenhouse gas emissions and their climate impact from yearly generated and collected waste, i.e., around **3.5 Million tons of CO_2-eq,** and in **1.2 Million tons of CO_2-eq**, respectively in BAU Scenario.

Greenhouse Gas House Emission Inventory of Baluchistan: The Estimated Greenhouse gas emission inventory of Baluchistan is given in Table 53 attached in the appendix, which shows a huge quantum of greenhouse gas emissions and their climate impact from yearly generated and collected waste, i.e., around **0.8 Million tons of CO_2-eq,** and in **0.3 Million tons of CO_2-eq**, respectively in the BAU Scenario.

Greenhouse Gas Emission Inventory of Azad Jammu and Kashmir: The Estimated Greenhouse gas emission inventory of Azad Jammu and Kashmir is given in Table 54 attached in the appendix. The greenhouse gas emissions form Islamabad and AJK are calculated along with climate impact from yearly generated and collected waste, i.e., around **0.5 million tons of CO_2-eq,** and in **0.3 Million tons of CO_2-eq**, respectively in the BAU Scenario.

Figure 10. Heat Maps of GHG and BC Emissions at the National Level





Source: Emissions Data Compiled during this study.

4.5. Economic Modelling for Provincial Capitals of Pakistan

SWM in provincial capitals of Pakistan continues to be an economic, environmental, and operational challenge for the country. This approach proposes an economic modeling potential to assess the financial viability and prioritization of MSW treatment alternatives in provincial capitals of Pakistan. A scenario-based economic analysis is performed, along with cost-benefit and multi-criteria analysis methods.

Integrated Waste Diversion Scenarios and Treatment Pathways: For Scenario 1, 2, and 3, all waste not captured by the diversion facilities is directed to engineered landfill with gas recovery. This ensures continuous environmental compliance and provides an initial source of supplementary energy generation. Scenario 4 modifies this approach to include thermal treatment for the final, minimal residue. The detailed breakdown of the integrated treatment train for each modeled scenario is explained in Table 10.

Table 10: Waste Diversion Scenarios

Scenario	Waste Diversion Target	Treatment Pathways (Diversion Portion)	Residual Management
1	**20%**	Composting (Organics) + Recycling Facility (Recyclables)	Landfilling with Gas Recovery
2	**40%**	Composting (50% Organics) + AD (50% Organics) + Recycling Facility (Recyclables)	
3	**60%**	Composting (50% Organics) + AD (50% Organics) + Recycling (50% Recyclables) + RDF Facility (50% Recyclables)	
4	**80%**	Composting (35% Organics) + AD (35% Organics) + MBT (30% Organics) + Recycling (50% Recyclables) + RDF Facility (50% Recyclables)	LFG (80%) + Incineration (20%)

Source: Authors assumptions/ Calculations.

The scenarios created for each provincial capital of Pakistan along with the collected and diverted waste amounts are given in the section below.

Karachi: The municipal solid waste generation in Karachi amounts to 12956 tons per day, whereas the effective collection rate reaches 9544 tons per day, indicating a substantial portion remaining unmanaged within the system. Waste diversion scenarios are explained in Table 11.

Table 11: Waste Diversion Scenarios for Karachi

Scenarios	Tonnage Diversion (t/d)	Compost (t/d)	Recyclables (t/d)	RDF (t/d)	MBT (t/d)	AD (t/d)	Incineration (t/d)	LFG Recovery form organic Waste (t/d)
S1	1909	1134	499	-	-	-	-	4574
S2	3818	1134	997	-	-	1134	-	3630
S3	5726	1701	792	704	-	1701	-	2686
S4	7635	1587	1056	938	1361	1587	603	1394

Source: Authors assumptions/ Calculations.

Details of scenarios developed along with waste diversion based on waste composition for Karachi are attached in the appendix from Table 55 to Table 58.

Lahore: The municipal solid waste generation in Lahore reaches 5000 tons per day, whereas the city's collection system manages around 4000 tons per day, leaving a considerable fraction uncollected and outside formal processing streams. Waste diversion scenarios are explained in Table 12.

Table 12: Waste Diversion Scenarios for Lahore

Scenarios	Tonnage Diversion (t/d)	Compost (t/d)	Recyclables (t/d)	RDF (t/d)	MBT (t/d)	AD (t/d)	Incineration (t/d)	LFG Recovery form organic Waste (t/d)
S1	794	412	263	-	-	-	-	1629
S2	1589	412	526	-	-	412	-	1296
S3	2383	618	501	288	-	618	-	962
S4	3177	577	667	384	495	577	254	503

Source: Authors assumptions/ Calculations.

Details of scenarios developed along with waste diversion based on waste composition for Karachi are attached in the appendix from Table 59 to Table 62.

Peshawar: The municipal solid waste generation in Peshawar is 1891 tons per day, while the formal collection system captures only 886 tons per day, indicating a significant volume that remains unmanaged within the urban environment. Waste diversion scenarios are explained in Table 13.

Table 13: Waste Diversion Scenarios for Peshawar

Scenarios	Tonnage Diversion (t/d)	Compost (t/d)	Recyclables (t/d)	RDF (t/d)	MBT (t/d)	AD (t/d)	Incineration (t/d)	LFG Recovery form organic Waste (t/d)
S1	177	121	38	-	-	-	-	427
S2	354	121	76	-	-	121	-	333
S3	532	181	59	55	-	181	-	240
S4	709	169	79	73	145	169	50	117

Source: Authors assumptions/ Calculations.

Details of scenarios developed along with waste diversion based on waste composition for Karachi are attached in the appendix from Table 63 to Table 66.

Quetta: Quetta generates 1249 tons of municipal solid waste each day while its formal system manages 758 tons daily which leaves a sizeable portion outside regulated handling. Waste diversion scenarios are explained in Table 14.

Table 14: Waste Diversion Scenarios for Quetta

Scenarios	Tonnage Diversion (t/d)	Compost (t/d)	Recyclables (t/d)	RDF (t/d)	MBT (t/d)	AD (t/d)	Incineration (t/d)	LFG Recovery form organic Waste (t/d)
S1	152	102	42	-	-	-	-	202
S2	303	102	84	-	-	102	-	316
S3	455	153	68	58	-	153	-	269
S4	606	143	91	77	123	143	36	48

Source: Authors assumptions/ Calculations.

Details of scenarios developed along with waste diversion based on waste composition for Karachi are attached in the appendix from Table 67 to Table 70.

Economic Assessment of Waste Diversion Scenarios: The economic assessment of the waste diversion scenarios included the calculation of the facility cost of the waste treatment option, the shadow cost, monthly rent, operational and maintenance cost and the human resource cost. The equation used for the calculation of facility cost is from (Iqbal et al.,2022a). Similarly, the calculations of the revenue generation are from (Iqbal et al., 2022a).

Technical and Operational Assumptions: These input data relate directly to the physical characteristics of the municipal solid waste stream and the expected technical performance outputs of the integrated treatment technologies (Table 15). Accurately modeling these parameters is vital given the highly heterogeneous nature of waste in the target cities.

Table 15: Technical and Operational Assumptions

Parameter	Value
Compost Recovery	200 kg/ton
Recycling Recovery Rate	90%

LFG Recovery Efficiency	**50%**
Biogas Production Potential	140 m^3/ton
Electricity Potential for AD	**296.8 kWh/ton**
RDF Recovery	**85%**

Source: IGES (2025).

Facility Cost Inputs (CAPEX and OPEX): The cost inputs are standardized on a capacity-based metric USD per ton per day (Kaza et al., 2018) to facilitate accurate scaling of the investment required for each of the four diversion scenarios across the various provincial capital capacities. These costs are converted into PKR to enhance the understanding of these financial models as explained at Table 16.

Table 16: CAPEX for Waste Treatment Options

Facility / Cost Type	Unit Value	Basis for Calculation
Composting CAPEX	PKR 1000000/ton	**(Urban Unit, 2024)**
Anaerobic Digestion (AD) CAPEX	PKR 91975/ton	**(Kaza et al., 2018)**
Recycling Facility CAPEX	PKR 1000000/ton	**(Urban Unit, 2024)**
RDF Facility CAPEX	PKR 226400/ton	**(Kaza et al., 2018)**
Incineration CAPEX	PKR 53770/ton	
MBT CAPEX	PKR 169800/ton	

Source: Authors' computations.

Revenue Generation Inputs: Project revenues are calculated based on the quantity of marketable outputs generated by each facility and the assumed guaranteed selling price under standard market conditions or Power Purchase Agreements (PPAs) as depicted at Table 17.

Table 17: Revenue Generation Data

Product / Revenue Source	Unit Sale Price	Basis for Calculation
Compost Price	PKR 20/kg	Based on market consultation
Paper-Cardboard Price	PKR 24/kg	Based on market consultation
Plastics	PKR 80/kg	Based on market consultation
Metal	PKR 127/kg	Based on market consultation
Glass	PKR 10/kg	Based on market consultation
Textile	PKR 6/kg	Based on market consultation
Biogas Sale Price	PKR 175/kg	The Hindu, Business Line (2024)
RDF Sale Price	PKR 10000/ton	Based on market consultation

Source: Authors' computations.

Carbon Financing: The economic evaluation of integrated solid waste management systems is incomplete without quantifying the financial benefits derived from the mitigation of greenhouse gas GHG emissions. This section details the methodology used to calculate potential Carbon Financing—a significant, non-traditional revenue stream—for each waste diversion scenario. The inclusion of this metric aligns the project's financial performance with global sustainability objectives and climate financing mechanisms.

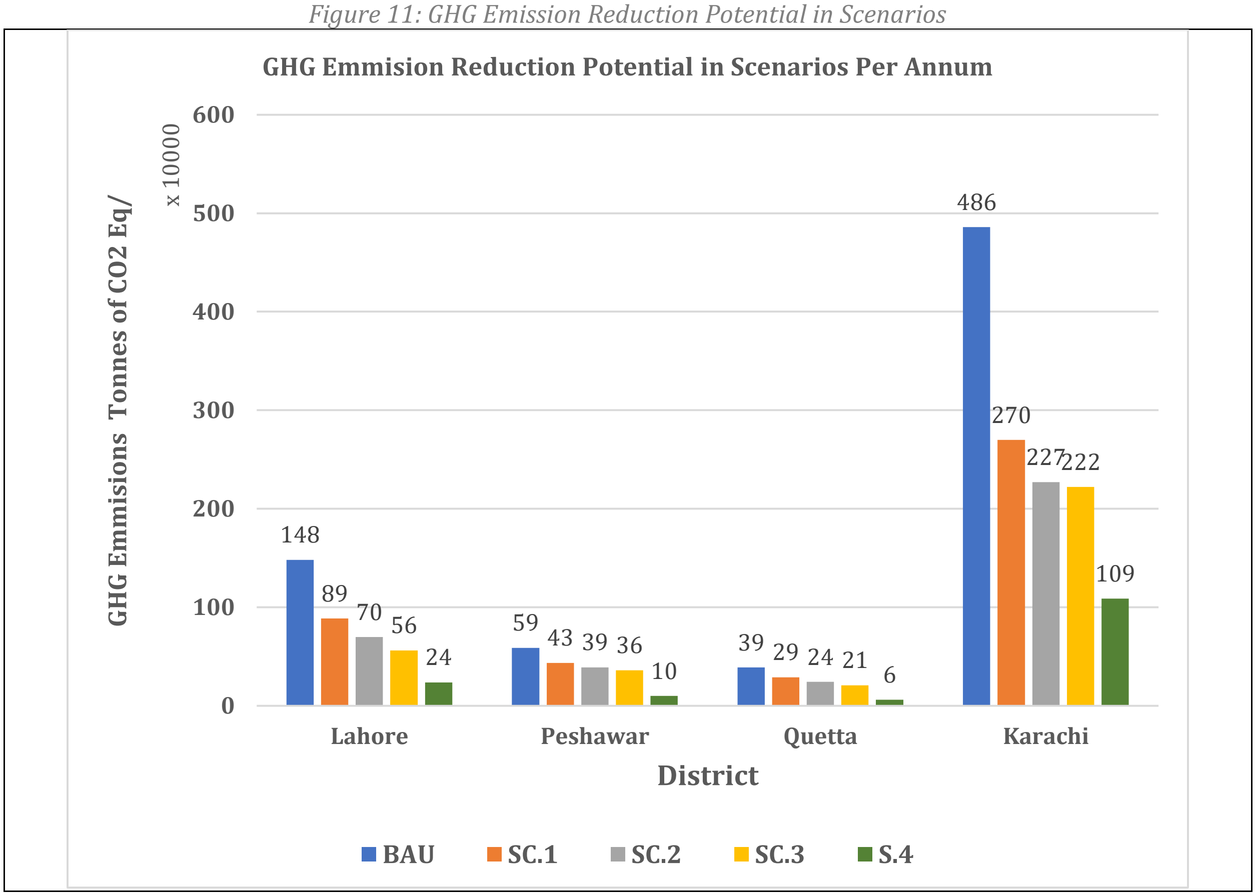
GHG Emission Reduction Assessment: The foundational step involved quantifying the positive environmental impact of shifting from conventional landfilling to resource recovery and advanced treatment technologies. For each of the four diversion scenarios 20% to 80%, a detailed assessment was performed to calculate emission reduction potential measured in tons of CO_2 equivalent (tCO_{2}-eq).

This reduction is primarily achieved by:

- **Avoided Methane Emissions:** By diverting organic waste from the landfill; where it would anaerobically decompose into methane, a potent GHG, the model quantifies the avoided emissions.
- **Product Substitution:** Replacing virgin materials with recovered products (compost, recyclables, RDF, and generating renewable energy (biogas, LFG energy, incineration energy) results in avoided emissions from conventional processes (fossil fuel burning, fertilizer production, virgin material extraction).

The net reduction in GHG emissions for each city and scenario serves as the foundational parameter for the carbon financing calculation, as shown in Fig. 11, and details are attached in the appendix in Table 71.

Figure 11: GHG Emission Reduction Potential in Scenarios



Source: Authors Own Computation through primary data analysis during study.

Carbon Credit Price and Valuation: To convert the environmental benefit into a quantifiable financial metric, a standardized Carbon Credit price is USD 5 (Pai, 2025) was established using a relevant market reference. This price reflects the assumed value of one $MtCO_2$-eq in an established or emerging carbon market. The selection of a robust reference ensures the valuation is grounded in current or projected market dynamics, enhancing the credibility of the revenue stream.

Carbon Financing Calculation: The final calculation for the total carbon financing revenue (Iqbal et al., 2022a) from each city based on emissions saving in each scenario as compared to BAU emission scenario is used to estimate the potential for carbon financing. Cities with larger waste generation, like Karachi and Lahore, achieve the biggest absolute and percentage reductions, while medium-sized cities show moderate but consistent improvements as explained in Table 18 & Fig. 12.

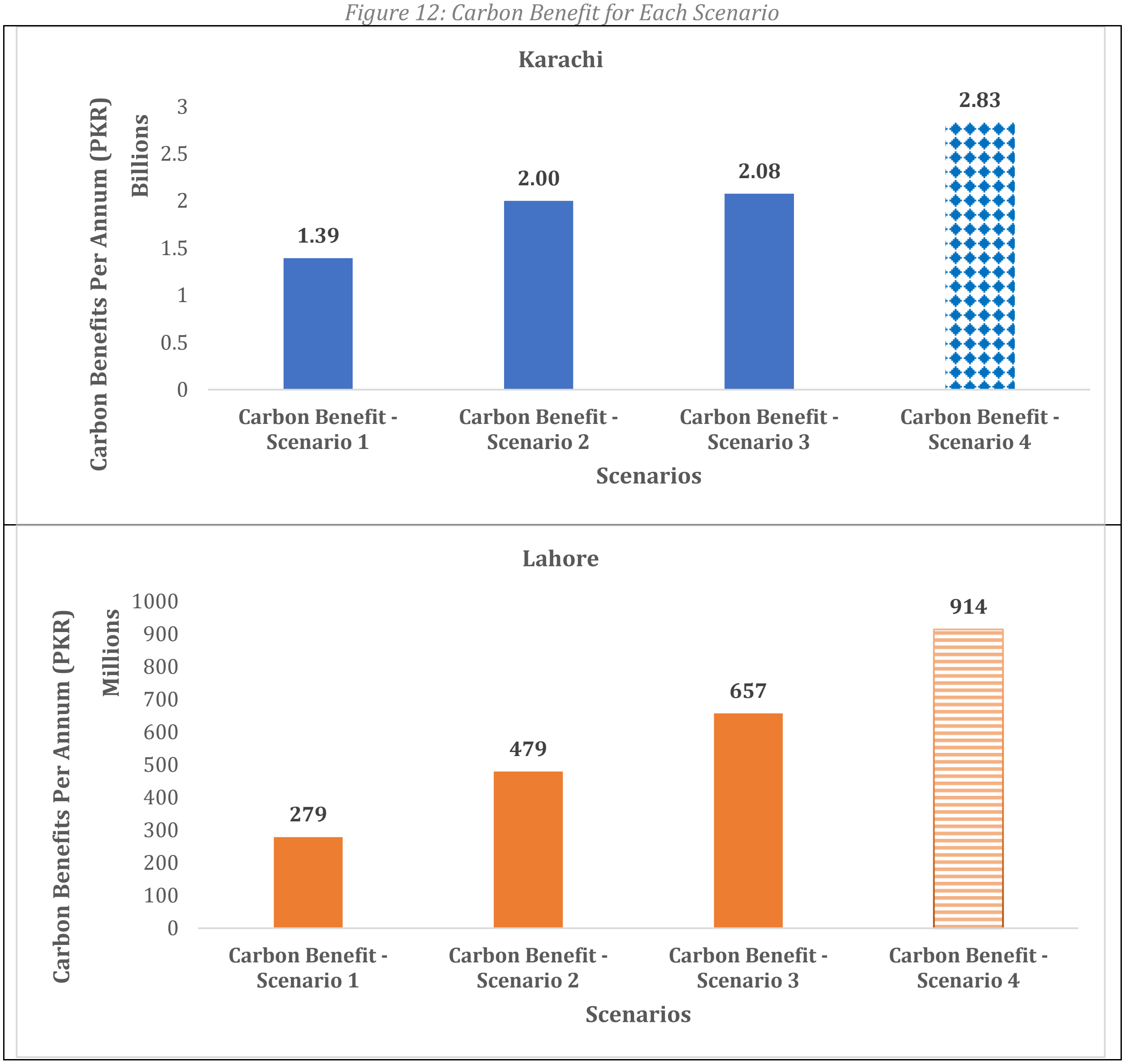
Table 18: Carbon Credit/ Financing Potential

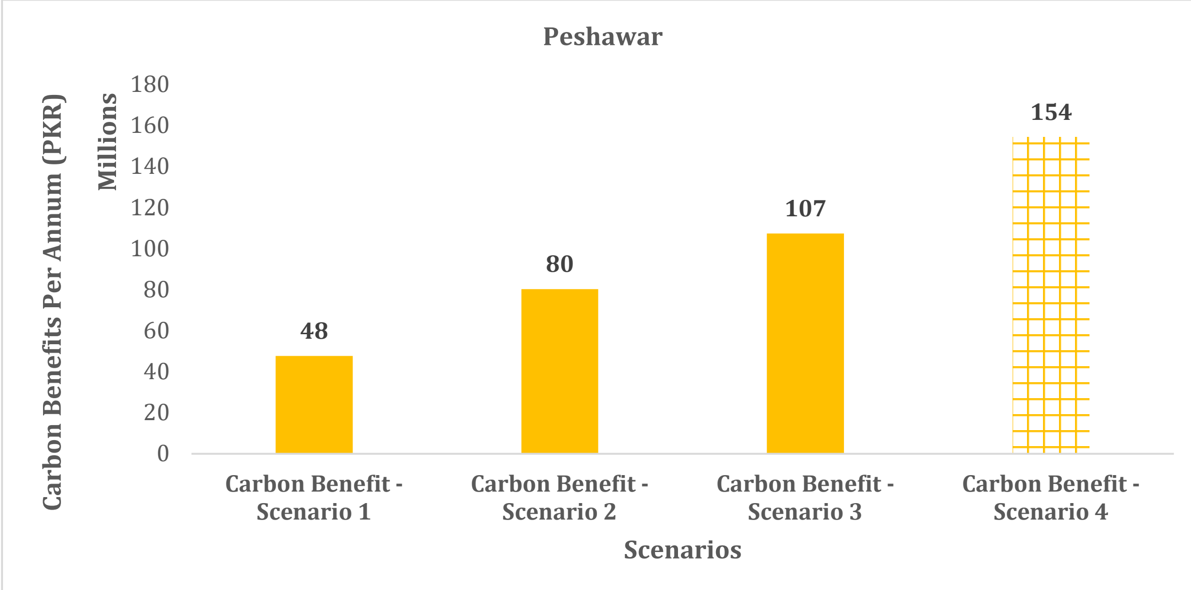
Waste Diversion Options	**Sectoral Emissions without Any Waste Diversion/ Treatment – BAU**		**Sectoral Emissions Reduction Potential with Waste Diversion/ Treatment**		**Environment Monitory Value / Economic Potential through emission savings**	
	District Name	Climate Impact from GHG Emissions – Yearly Generated Waste (Tonnes of CO2-eq.)	Climate Impact from GHG Emissions – Yearly Generated Waste after Waste Diversion Targets (Tons of CO2-eq.)	Emissions Reduction/ Saving from Yearly Generated Waste (Tons of CO2-eq.)	Carbon Benefits Potential Per annum (PKR)	Carbon Benefits Potential Per annum PKR-Millions
Scenario 1- 20% Diversion						
Compost Recycling Landfilling With Landfill Gas Recovery	**Lahore**	1,480,836	885,241	595,596 **(40%)**	278,738,786	**278.7**
	Karachi	4,859,792	2,697,743	2,162,049 **(44%)**	139,452,1757	**1,394.5**
	Peshawar	587,333	434,800	152,533 **(25%)**	47,552,227	**47.5**
	Quetta	388,241	288,544	99,697 **(25%)**	30,799,490	**30.7**
Scenario 2 - 40 % Waste Diversion						
Compost Aerobic Digestion Recycling Landfilling with Landfill Gas Recovery	**Lahore**	1,480,836	696,414	784,422 **(52%)**	479,134,239	**479.1**
	Karachi	4,859,792	2,270,764	2,589,028 **(53%)**	2,001,318,709	**2,001.3**
	Peshawar	587,333	389,283	198,050 **(33%)**	80,182,555	**80.1**
	Quetta	388,241	240,836	147,406 **(37%)**	67,163,943	**67.1**
Scenario 3- 60 % Waste Diversion						
Compost Aerobic Digestion Recycling Refused Derived Fuel Landfilling with	**Lahore**	1,480,836	561,683	919,153 **(62%)**	657,377,978	**657.3**
	Karachi	4,859,792	2,220,309	2,639,483 **(54%)**	2,077,272,937	**2,077.2**
	Peshawar	587,333	358,294	229,038 **(38%)**	107,267,761	**107.2**
	Quetta	388,241	206,730	181,512 **(46%)**	101,908,023	**101.9**

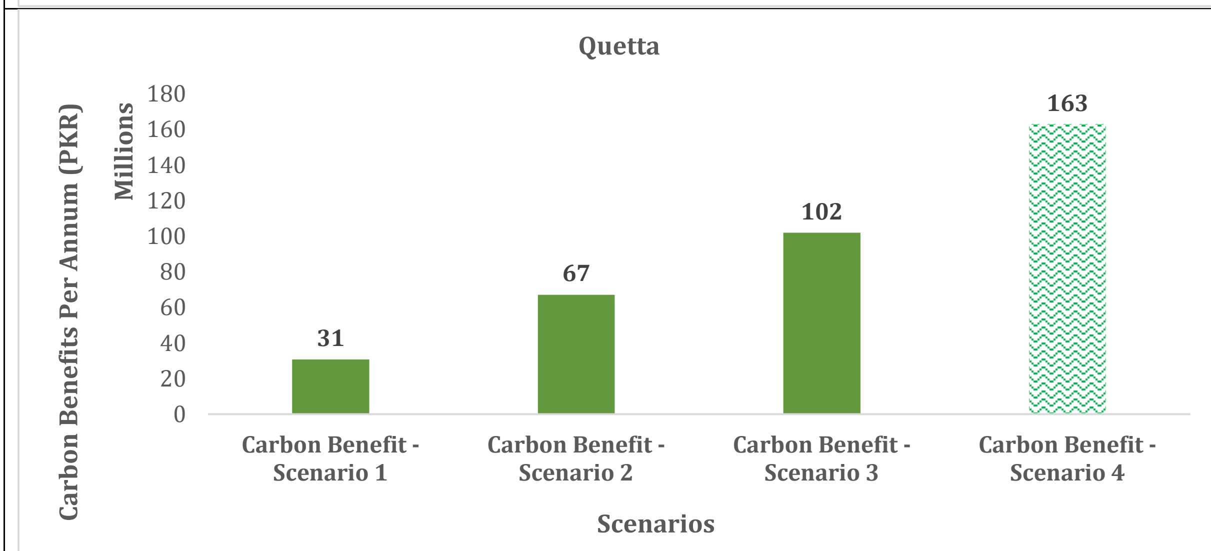
Landfill Gas Recovery							
Scenario 4- 80 % Waste Diversion							
Compost/ Recycling Aerobic Digestion/MBT **Refused Derived Fuel /Incineration Landfilling with Landfill Gas Recovery**		**Lahore**	1,480,836	397,096	1,083,741 **(73%)**	914,209,648	**914.2**
		Karachi	4,859,792	1,782,982	3,076,809 **(63%)**	2,829,876,311	**2,829.8**
		Peshawar	587,333	312,547	274,785 **(46%)**	154,275,518	**154.2**
		Quetta	388,241	158,747	229,495 **(59%)**	162,840,304	**162.8**

Source: Authors assumptions/ Calculations.

Figure 12: Carbon Benefit for Each Scenario







Source: Authors' computations.

Economic Potential from Scenarios Development: The table presents the Total Economic Potential (EP) generated under four different scenarios for major cities in Pakistan. The EP is expressed in Million PKR; both on a per-day and per-annum basis. This EP includes the sale of waste products such as compost, recyclables, RDF, and bio-gas including the environmental monetary benefit values as explained in Table 19, Fig. 13 and Fig. 14.

Karachi: Karachi shows the **highest economic potential** among all cities under every scenario.

- Under **Scenario-1**, the EP starts at **PKR 17 million /day** and **PKR 5 billion /year**.
- By **Scenario-4**, the potential increases significantly to **PKR 63 million /day** and **PKR 20 billion / year**.
  This reflects Karachi's large population and waste-generation capacity, offering substantial revenue opportunities.

Lahore: Lahore ranks second in economic potential.

- In **Scenario-1**, EP is **PKR 8 million /day** and **PKR 2 billion /year**.
- Under **Scenario-4**, EP reaches **PKR 30 million /day**, translating to **PKR 9 billion /year**. This steady rise across scenarios highlights the city's strong potential for resource recovery and waste-to-value systems.

Peshawar: Peshawar demonstrates **modest economic potential** relative to Karachi and Lahore.

- EP begins at **PKR 1 million /day** (PKR 0.3 billion /year) in **Scenario-1**.
- With **Scenario-4**, EP increases to **PKR 6 million /day** and **PKR 2 billion /year**. Although smaller in scale, the gains show promising opportunities under improved waste-management scenarios.

Quetta: Quetta's economic potential is similar to Peshawar's.

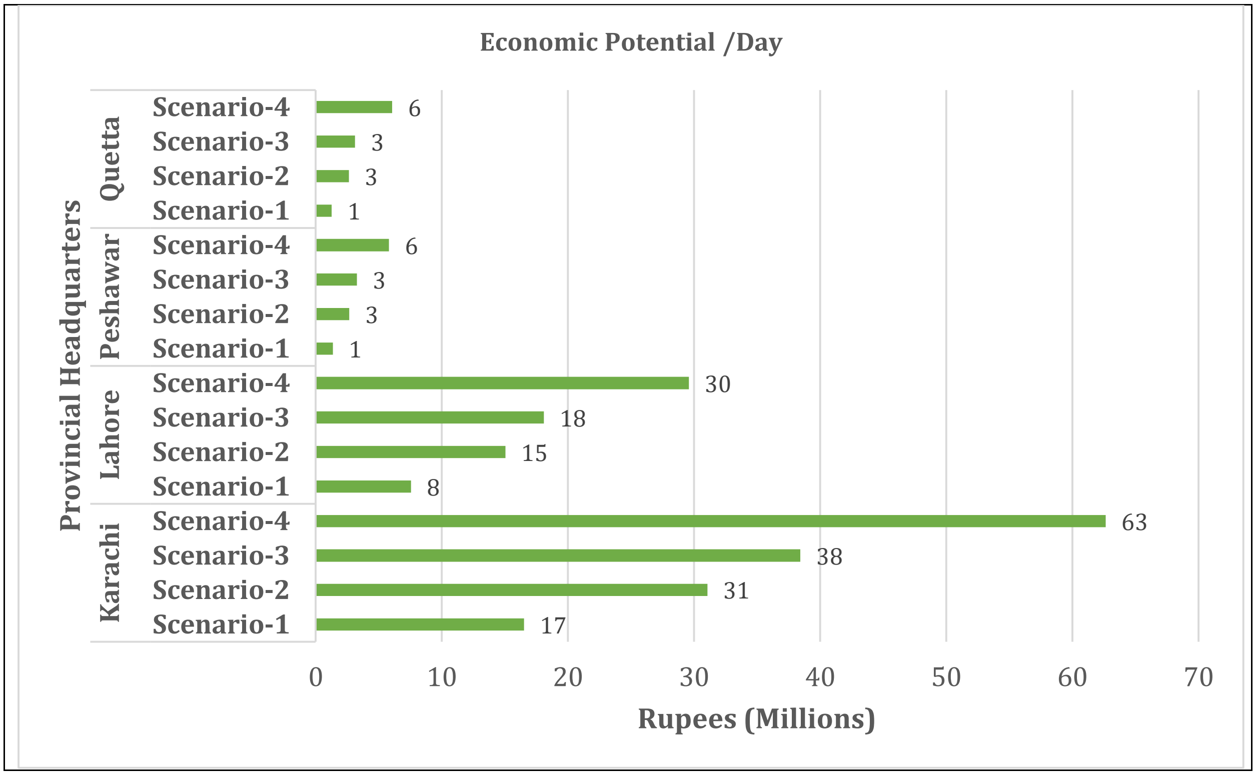
- **Scenario-1** results in **PKR 1 million /day** and **PKR 0.3 billion /year**.
- Under **Scenario-4**, EP rises to **PKR 6 million /day** and **PKR 2 billion /year**. The progressive increase across scenarios indicates strong benefits from enhanced waste-processing interventions.

Table 19: Economic Potential of Waste Sector

Districts	Scenario	EP (per day) Millions	EP (per annum) (Millions)
Karachi	Scenario-1	17	5,289
	Scenario-2	31	9,939
	Scenario-3	38	12,300
	Scenario-4	63	20,042
Lahore	Scenario-1	8	2,415
	Scenario-2	15	4,813
	Scenario-3	18	5,786
	Scenario-4	30	9,470
Peshawar	Scenario-1	1	435
	Scenario-2	3	852
	Scenario-3	3	1,045
	Scenario-4	6	1,861
Quetta	Scenario-1	1	405
	Scenario-2	3	842
	Scenario-3	3	997
	Scenario-4	6	1,940

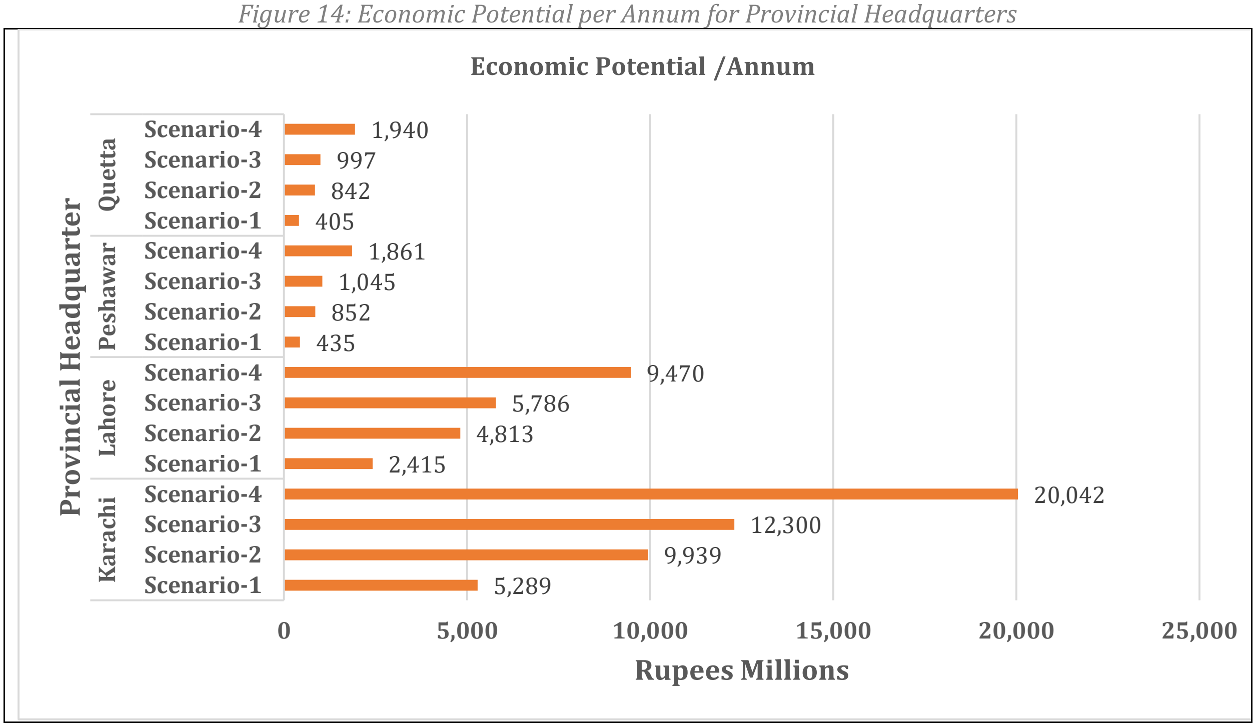
Source: Authors' computations.

Figure 13: Economic Potential per Day for Provincial Headquarters



Source: Authors assumptions/Calculations.

Figure 14: Economic Potential per Annum for Provincial Headquarters



Source: Authors assumptions/Calculations.

4.6. Prioritizing MSW Treatment Options through Analytical Hierarchy Process (AHP)

Multi-criteria decision analysis (MCDA) methods, and more particularly the Analytical Hierarchy Process (AHP), have been chosen because; (1) It has a hierarchy of decision levels that is systematically established; (2) A comparison of the relative importance of one criterion versus another or one alternative versus another allows a quantification of the initially subjective judgments; (3) This quantification is characterized by a global consistency, the reliability of which can be verified; (4) The successive weightings associated with the criteria or alternatives, result in a ranking of the alternatives by synthesis.

Analytical Hierarchy Process (AHP): Steps-1 to 4 were taken to break down the decision problem into goals, criteria, and alternatives. This helps present local operational, economic, and environmental conditions: Step-1 provides background context, Step-2 reflects the relative importance of criteria, Step-3 ensures reliability of judgments through consistency assessment, and Step-4 consolidates components into a decision framework. Collectively, these steps provide a set of rankings that are logically and practically robust in real-world waste management scenarios.

Step – 1: SWM Ranking Model Development: Formulate the decision model, including the overall objective, the set of criteria, and the set of treatment alternatives. The overall objective is to find the most appropriate MSW treatment alternative under local conditions. The main economic, environmental, technical, and operational criteria are chosen to be consistent with the actual planning process priorities. A set of reasonable MSW treatment alternatives is determined for systematic comparison in the AHP model (Table 20).

Table 20: Model Development

Goal	**MSW Treatment Options**									
Criteria	Criteria									
	1	2	3	4	5	6	7	8	9	10
	Operating Cost	Investment Cost	Emission Reduction	Carbon Credit Potential	Market Sale	Land Requirement	Energy Requirement	Sound Technology	Environment Mitigation	Coherence with Waste Composition
Alternatives	Alternatives									
	1	2	3	4	5	6	7	-	-	-
	Compost	AD	Recycling	Incineration	RDF	MBT	LFG	-	-	-

Source: Authors assumptions/Calculations.

Step – 2: Determination of Importance of Various Attributes or Criteria with respect to Goal: In the present stage, each criterion was pairwise compared with the remaining criteria, using Saaty's scale (Saaty, 1987), to determine their relative importance. Pairwise comparisons of each criterion with respect to the other criteria were made to indicate the relative effect of each criterion towards the accomplishment of the stated objective as explained at Table 21. Expert opinion, literature evidence and their practical significance in the local waste management context were used to form the judgments results further normalized as explained at Table 74 attached in appendix.

Table 21: Pairwise Comparison Matrix

Criteria	Operating Cost	Investment Cost	Emission Reduction	Carbon Credit	Market Sale	Land Requirement	Energy Requirement	Sound Technology	Environment Mitigation	Coherence with waste

			Potential	Potential						composition
Operating Cost	1	0.33	0.14	0.14	0.33	0.25	0.25	0.2	0.2	0.2
Investment Cost	3	1	0.2	0.2	0.25	0.2	0.33	0.2	0.2	0.2
Emission Reduction Potential	7	5	1	1	0.2	0.33	0.33	0.2	0.33	0.33
Carbon Credit Potential	7	5	1	1	0.33	0.33	0.33	0.33	0.33	0.33
Market Sale	3	4	5	3	1	3	4	3	3	3
Land Requirement	4	5	3	3	0.33	1	0.33	0.2	0.33	0.33
Energy Requirement	4	3	3	3	0.25	3	1	0.2	5	0.33
Sound Technology	5	5	5	3	0.33	5	5	1	3	0.2
Environment Mitigation	5	5	3	3	0.33	3	0.2	0.33	1	0.33
Coherence with waste composition	5	5	3	3	0.33	3	3	5	3	1
Sum	44	38.33	24.34	20.34	3.7	19.12	14.78	10.67	16.4	6.27

Source: Authors assumptions/Calculations.

The result pairwise comparison matrix was then formed, which converted the qualitative assessments to quantitative. This then allowed for the analysis of the tradeoffs between criteria, which is an important step in capturing the priorities of the decision in AHP attached in appendix (Table 75).

Step – 3: Calculating the Consistency: Consistency check is important to ensure pairwise judgements are logically consistent. Weighted sums are computed from the criterion weights and normalized values. Then λmax is calculated which is used to calculate the Consistency Index and the Consistency Ratio. A satisfactory consistency ratio indicates that the comparisons are consistent and can be used for the decision attached in appendix (Table 76).

Step – 4: Modal/ Component Mode Synthesis and Decision Making: The final step is unified criterion weights with alternative performance values through construction and normalization of the decision matrix attached in appendix (Table 77).

Each alternative was evaluated against the all criteria using the standardized values to ensure comparability across the different measurement units attached in appendix (Table 78).

These normalized scores were multiplied by the corresponding criterion weights to generate the weighted scores which were then aggregated to obtain the overall priority values for each treatment option (Table 22).

Table 22: Decision Matrix

Criteria	Operating Cost	Investment Cost	Emission Reduction Potential	Carbon Credit Potential	Market Sale	Land Requirement	Energy Requirement	Sound Technology	Environment Mitigation	Coherence with waste composition
Weights	0.02	0.03	0.06	0.06	0.22	0.07	0.11	0.16	0.09	0.18
Compost	0.01	0.03	0.04	0.06	0.01	0.02	0.02	0.08	0.09	0.18
AD	0.01	0.01	0.03	0.02	0.01	0.03	0.01	0.05	0.05	0.09
Recycling	0.02	0.03	0.06	0.05	0.22	0.02	0.11	0.02	0.03	0.04
Incineration	0.01	0.01	0.02	0.01	0.03	0.07	0.00	0.04	0.01	0.03
RDF	0.00	0.03	0.01	0.01	0.03	0.04	0.00	0.03	0.02	0.03
MBT	0.00	0.01	0.04	0.01	0.03	0.06	0.01	0.03	0.02	0.06
LFG	0.01	0.10	0.03	0.05	0.01	0.01	0.03	0.16	0.02	0.04

Source: Authors assumptions/Calculations.

The resulting scores enabled clear ranking of the alternatives, providing an evidence-based basis for identifying the most suitable MSW treatment solution under the local conditions (Table 23).

Table 23: Final AHP Ranking

Alternatives	Rank Score	Ranking
Recycling	0.60	1
Compost	0.55	2
LFG	0.46	3
AD	0.31	4
MBT	0.27	5
Incineration	0.22	6
RDF	0.20	7

Source: Authors assumptions/Calculations.

Cost Benefit Analysis: In order to provide a complementary perspective, a Cost-benefit analysis was also performed using the AHP structure and considering only the financial parameters. CAPEX and OPEX were analyzed separately, in order to better reflect the initial investment requirement, as well as long-term operating feasibility. The resulting ranking, considering CAPEX only, places landfilling with gas recovery in first place while analysis based on OPEX only, ranks recycling in first place (Table 24).

Table 24: CAPEX and OPEX Ranking

Ranking	**CAPEX Analysis**		**OPEX Analysis**	
	Alternative	**Rank Score**	**Alternative**	**Rank Score**
1	LFG	0.366	Recycling	0.257
2	Compost	0.042	LFG	0.188
3	RDF	0.042	Compost	0.085
4	Recycling	0.039	Incineration	0.045
5	AD	0.007	AD	0.015
6	MBT	0.005	RDF	0.007
7	Incineration	0.003	MBT	0.004

Source: Authors assumptions/Calculations.

The Combined cost analysis results are summarized in the Table 25 where Landfilling with Gas Recovery ranked first overall followed by the Recycling and Composting.

Table 25: Final Cost Benefit Analysis Ranking

Alternatives	**Rank Score**	**Ranking**
LFG	0.555	1
Recycling	0.296	2
Compost	0.128	3
RDF	0.051	4
Incineration	0.048	5
AD	0.023	6
MBT	0.010	7

Source: Authors assumptions/Calculations.

4.7. Sectoral Policy Guidelines at National Level

Alignment with National and Global Frameworks: The Ministry of Climate Change and the Environment of Pakistan submitted updated NDCs in 2025 with a goal to reduce emissions by 50% in 2035. This included 17% unconditionally with domestic resources and 33% conditionally, with international climate finance, technology transfer and capacity building support (GOP, 2025). The waste sector related GHG emissions inventory as reflected in NDCs is depicted in Table 26.

Table 26. Emissions from Waste Sector and Its Alignment with NDCS Over the Period

Sector Inventory in Pakistan NDCs	Years					
	1994	2012	2015	2018	2021	2024/25
Waste Sector Emissions (Mt CO_2-eq)	4.45	10.54	15.65	21.72	32.44	-
Total Emissions (All Sector) (Mt CO_2-eq)	181.70	374.11	408.15	489.87	521.47	585.08
Share of Waste Sector in Total Emissions (%)	2.4%	3%	4%	4.4%	6.22%	9%
Alignment of Waste Sector with NDCs (Some examples)	• Banning on single use plastics. • Promote reuse, source reduction and recycling of waste • SDG 11, 12, and 13					

Source: (GOP, 2025).

The potential of waste sector is thoroughly studied and opportunities are explored for its alignment with the SDGs to achieve the sustainability of sector as explained in Table 73 attached in appendix.

4.8. Sectoral Policy Components

For the national SWM policy six components are included: waste minimization, storage/ collection/ transport, recycling/ reuse, treatment, disposal and the institutional framework.

Waste Prevention and Behavioral Change: Strategy for waste minimization is explained as follows:

a) Awareness for waste prevention at source
b) Review of municipal bylaws for compulsory source segregation.
c) Curriculum-based environmental education for long-term behavioral change in schools
d) Move away from mixed-waste collection towards separate 3-bin system for dry, wet and metal/electronics waste streams in a phased manner.
e) Reward systems for people segregating waste at different levels of waste hierarchy

Behavior change mode is explained in Table 27.

Table 27. Behavior Changes Modes, Instructions and Agents

Mode of Behavior Change	Behavior change Instructions	Strategy Agents
Producer pay principle: Extended Producer Responsibility (EPR) and Product Stewardship concept	The local government should promote the EPR concept in bylaws and regulations to make local industries responsible and accountable for the product entire lifecycle and material recovery.	• WMCs • Municipal Corporation • LG&CD Department • Government may support formulation of PROs at district/ divisional level with coordination of Chamber of Commerce
DtD waste collection alignment with source segregation and waste prevention	WMCs have implemented DtD waste collection system on cost recovery basis and now it is easy to integrate the concept of waste prevention and source segregation at this stage.	
Producer Responsibility Organizations (PROs)	PROs should be established at local level to support the minimization of waste at industrial level and also help in cost recovery against waste collection.	

Source: Author's computations.

Waste Storage, Collection and Transportation: Appropriate storage, collection and transportation is a key element in the SWM as explained in following section.

Waste Storage: It includes:

- At source: The strategy of segregation at source through colour-coded bins
- Community level: Provision of communal storage containers result in reduced littering, and better quality of recyclables.

Waste Collection: It includes:

- Focus on areas with high waste generation, efficient route design with proper planning of collection frequency
- Music/jingles on vehicles informing public about waste collection schedule.
- Cooperation from the local community and residents.
- Mobile transfer stations to be promoted.

Waste Transportation: It includes:

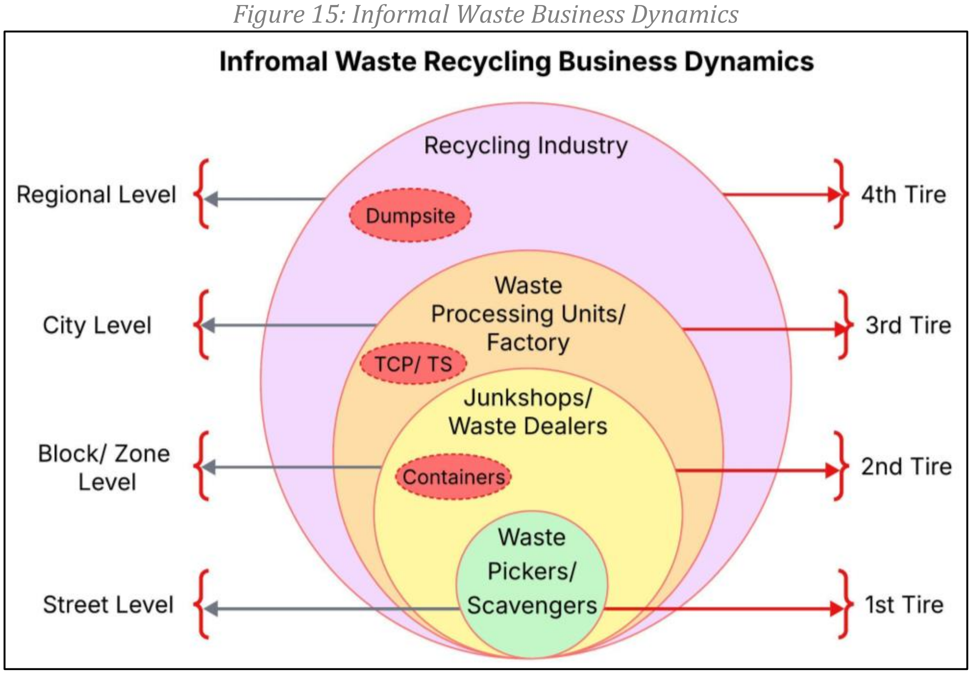
- Upgrading of fleets, weighbridges and digital tracking.
- Waste collection personnel training; route optimization (using mathematical optimization, such as graph theory and vehicle routing problems (VRPs), Artificial intelligence (AI), Geographical information systems (GIS), Internet of things (IoT) technology) to improve efficiency (fuel saving, reduction of black carbon emissions).
- Use of performance-based contracts and PPPs.

Waste Recycling and Reuse: It includes:

- Launch baseline surveys to map scavengers, junk dealers and informal recyclers, initiate a municipal register for informal workers, issue IDs and open access to trainings and protective equipment.
- Buy-back centers and reuse facilities through land allocation, tax exemptions or co-financing.
- Boost social acceptance of informal recyclers with awareness raising campaigns and in schools and communities.

Integration of Informal Waste Sector: Informal sector of waste pickers recovers most of recyclables prior to landfilling. 1st tier: scavengers separate source material; 2nd tier: waste dealers and junkshops; 3rd tier: local processing and refining; 4th tier: recycling industry using materials for manufacturing new products (Fig. 15).

Figure 15: Informal Waste Business Dynamics



Source: Author's computations.

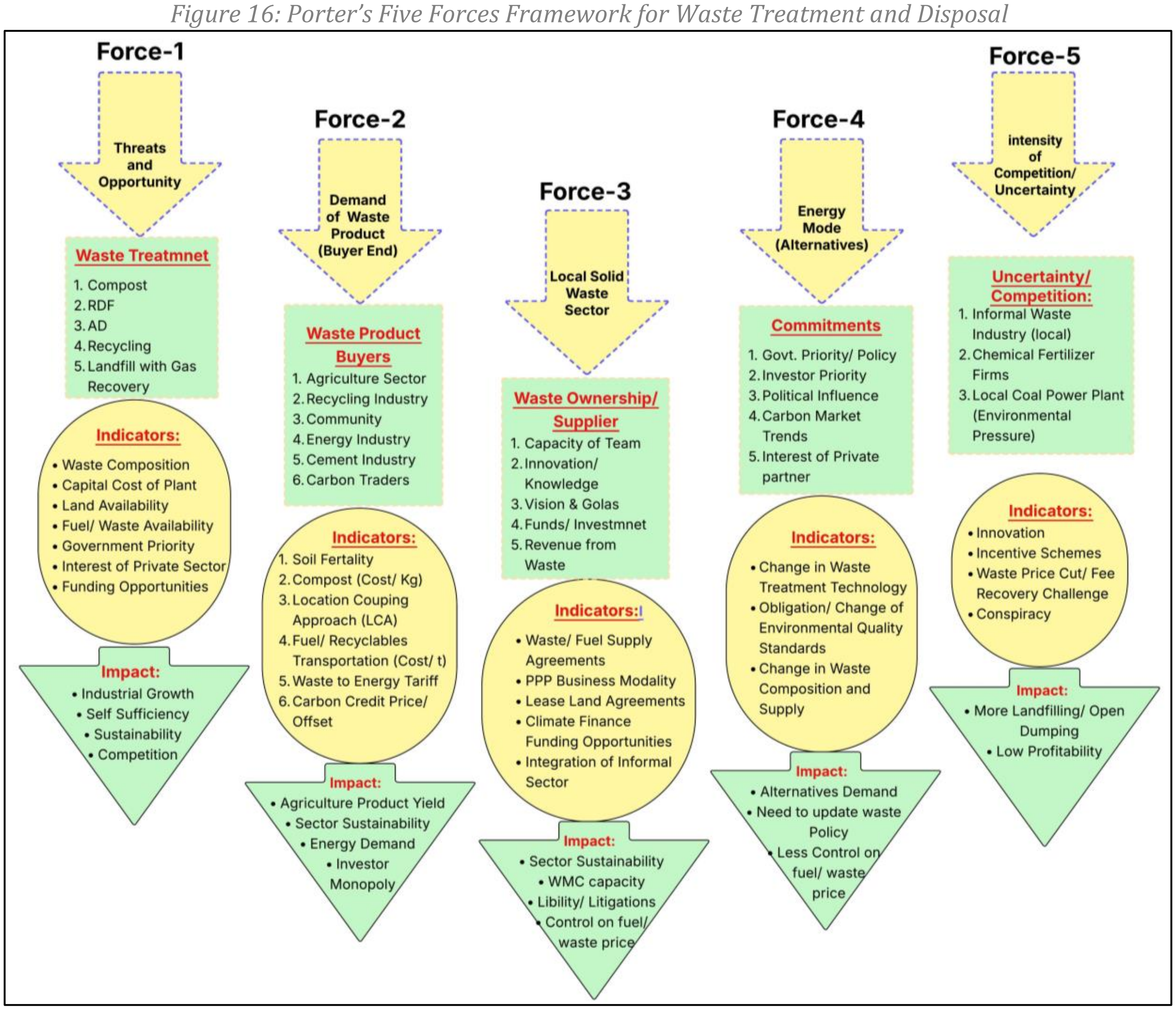
We have proposed two integrational models for the informal sector. The horizontal integration model and vertical integration model. Horizontal integration includes registration of all junkshops/

middlemen; this approach will support in monitoring of recovered waste, status of pickers, and data collection of recycling industry; and strict implementation of labor and safety laws. Vertical integration includes to set-up buy-back centers, which would buy recyclables directly from waste pickers, with opportunity to sell recovered material to recycling industry at part of local government.

Waste Treatment and Disposal: We proposed waste treatment and disposal strategy based on benchmark indicators including (Porter, 2008); this strategy supports to analyses sectoral potential for transitioning towards a CE concept (Fig. 16).

- Force-1 will evaluate the opportunities and threats in new products such as organic compost, biogas, RDF.
- Force-2 will evaluate buyer expectations directly shaping the market trend.
- Force-3 will focus on the raw material supply base, which will only be municipality.
- Force-4 will explore alternative ways of using the waste as energy, fuel, and fertilizer.
- Force-5 will address competition and innovation in waste sector.

Figure 16: Porter's Five Forces Framework for Waste Treatment and Disposal

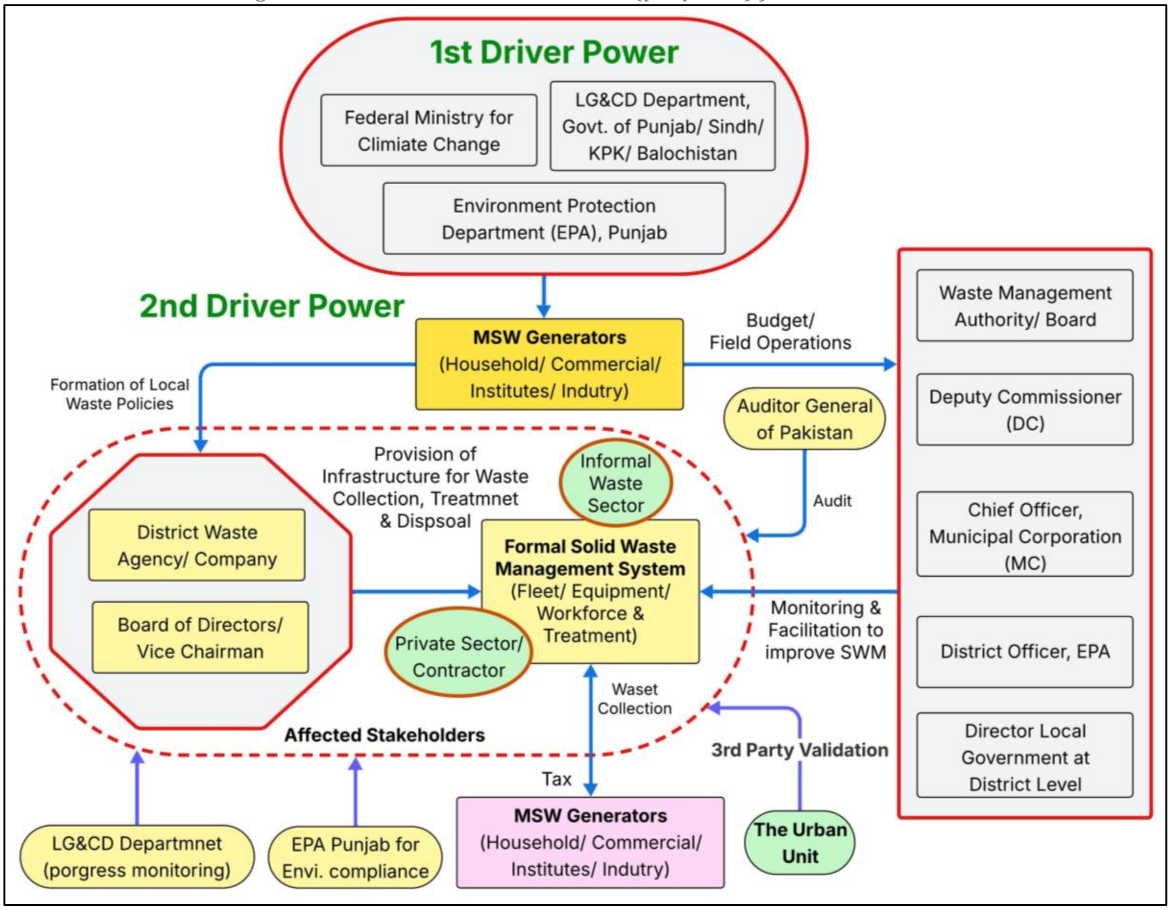


Source: Porter, 2008.

4.9. Proposed Institutional Framework

A robust institutional set-up will play a pivotal role in the implementation of sectoral strategy at national level. Ministry for Climate Change, provincial EPAs, LG&CD, municipal corporations, NGOs, and academia are stakeholders in the processes to increase sectoral efficiency as explained in Fig. 17.

Figure 17: Institutional Framework (proposed) for SWM Sector



Source: Authors' computations.

CONCLUSION

Pakistan is producing about 46 million tons of municipal solid waste per year with collection efficiency varies from 30% to 60% in Sindh, 70% to 80% in Punjab, 30% to 50% in Balochistan, KPK 30% to 60%, and Islamabad at 75%. However, policymakers have prioritized the waste sector as evident from the initiatives taken by all provincial governments to improve the waste collection and transportation with average national waste collection efficiency at 55% with open waste disposal during the last one and half decade. In the absence of any waste treatment and scientific waste disposal strategy, the sector is still considering as liability rather than exploring its potential to transform into resource to shed the financial burden on public exchequers. Fragmented operational models are being implemented in all provinces with national spending of Rs. 221 billion per annum, need unify approach to sustain the sector.

The total emissions from waste sector are estimated at 26.5 million tons of CO2-eq per annum with emissions of 1034 tons' black carbon from yearly generated waste. However, from yearly collected waste the sector is responsible for emitting 18.5 million tons of CO2-eq with 722 tons of BC emissions excluding sludge waste. Its share is about 9% in total GHG emission from all sector (585 million tons of CO2-eq. 2024). As per ministry's submitted report to UNFCCC in 2022, the MSW sector's emissions was about 13 million tons of CO2-eq per annum (excluding sludge waste), however our results show an increase in GHG emissions from generated waste at 50%, and collected waste at 31% in 2025.

RECOMMENDATION

The sector has potential to reduce the emissions up to 73% by diverting 80% waste from landfills for waste treatment, i.e., compost, AD, MBT, RDF, recycling, incineration, and landfill with LFG recovery. The economic and environmental potential show that the sector can generate up to 40% revenue money to meet its expenditures thus paving the way towards self-sufficiency. Furthermore, we have also prioritized the waste treatment options for Pakistan based on physical (>50% organic waste) and chemical (>50% moisture with 21% ash contents) waste composition by following the methodology of AHP of MCDM approach. We found that establishment of Material Recovery Facility (MRF) for recovery of recyclables (priority one) and compost (priority two) along with recovery of landfill gas (priority three) are more feasible options for waste treatment. However, based on cost benefit analysis, the MCDM has prioritize the landfill with LFG recovery (priority one), recycling (second priority), compositing (third priority), and RDF is found at fourth priority. Incineration, and MBT are found least options for local waste treatment and disposal.

Furthermore, this research will support federal MOCC&EC regarding waste sector emissions inventory and help in defining the sectoral targets at provincial level. The policy guidelines on waste diversion for treatment will support in achieving the emission reduction targets thus aligning the sector to meet international commitments (NDCs targets and SDGs) by 2030 and beyond.

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APPENDIX

Table 28. Waste Comparative Analysis at National Level

Research Reference	Study Area	Waste Generation Rate	Scope of Research	Waste Composition Data	GHG Emissions	Policy/ Planning Tools Used	Key Findings
(Akbar et al., 2024)	Rawalpindi (Peri-urban)	×	Analysis of attitudes of Household practices and awareness towards SWM in peri–urban settings.	✓	×	Household surveys, statistical analysis	Awareness campaigns for sustainable SWM and identification of behavioral gaps
(Ali et al., 2023)	Peshawar	0.474 kg per capita	Quantification of waste diversion and recovery rate	✓	×	Waste characterization studies	Variation of recovery rates by waste type; significant diversion potential
(World Bank, 2010)	Multan	0.41 Kg per capita	Examination of the SWM system and the feasibility of building a treatment facility	×	×	Feasibility study, technical and financial analysis	Highlights of financial and technological challenges in the operation and building of waste water treatment and its infrastructure
(Batool et al., 2008)	Karachi	(0.76 kg/cap/day)	Analysis of system wide waste flow using MFA	✓	×	Material Flow Analysis (MFA)	Reveals inefficiencies in collection and recycling streams
(Batool et al., 2008)	Lahore	×	Analysis of the Economic potential of recycling business	✓	×	Economic analysis, surveys	Significant income generation through recycling of informal sector especially
(Jabeen et al., 2017.)	Iqbal Town (Lahore)	×	Factors affecting residential waste generation.	✓	×	Household surveys, statistical analysis	The effect of household size and socio-economic status on waste composition
(Ilmas et al., 2018)	Multiple urban centers	×	Potential of MSW in Pakistan with respect to Energy.	✓	×	Calorific value analysis	Proper segregation of MSW can prove to be a viable energy resource
(Iqbal et al., 2022a)	Pakistan (national scale)	✓	SWM model for both environment and economics.	✓	✓	Integrated sustainable model	Advocating for the integrated waste policy framework for Pakistan

(Iqbal et al., 2023)	Lahore	✓	SWM sector evolution in Lahore	✓	×	Institutional analysis	Highlighting the improvements and noting of gaps in waste efficiency
(Khan et al., 2024)	Peshawar	×	Use of GIS and modeling to optimize SWM sector	×	×	Linear mathematical modeling, GIS	Improving efficiency through optimized routes and collection schedules
(Muhammad et al., 2024)	Quetta	×	Assessment of SWM system in Quetta.	✓	×	Field surveys, stakeholder interviews	Identification of key bottlenecks in the process of collection and disposal
(Quetta Municipal Corporation, 2015)	Quetta	×	Characterization report for MSW which includes physical and chemical analysis of solid waste.	✓	×	ASTM D 5231-92	Baseline waste composition data/Findings on the existing composition of Quetta City.
(Sandhu & Waheed, 2021)	Islamabad	×	Case study for Waste-to-wealth	✓	×	Case study method	Demonstration of economic potential of waste valorization
(Shahid et al., 2022.)	Karachi	×	Study on generation and composition	✓	×	Field sampling	Baseline data for Karachi's waste streams
(Zia et al., 2017)	Islamabad	×	Influence of income level and seasons on waste	✓	×	Seasonal & socio-economic analysis	Variation in composition and quantity with respect to income and season
This Study	30% Population of whole Pakistan	✓	Recommendation of the most suitable treatment options	✓	✓	Mix method/IGES EQT Calculator for emission calculations & AHP tool for policy making	Presentation of sustainable and climate resilient solution using the AHP tool with its policy driven approach.

Table 29. Waste Comparative Analysis of Developed Countries

Research Reference	Area of Research	Scope / Objective	Methodology	GHG Emissions Discussed	Country	Key Findings
(Laurent et al., 2014)	U.S – MSW & climate impacts	To analyse the fluctuations in the emissions of greenhouse gases caused by the processes of municipal solid waste management in the United States in 1974-1997, when much attention was drawn to environmental pollution and the government made several decisions.	Life Cycle Assessment (LCA) using the EPA's Decision Support Tool (DST).	✓	U.S	Whereas the production of municipal solid waste has doubled, adoption of recycling and waste-to-energy projects and landfill gas recovery have resulted in substantial greenhouse gas emission cuts.
(Wünsch & Tsybina, 2022)	Russia – MSW mitigation scenarios	Evaluation of waste reforms (2022 to 2030) on greenhouse gas emissions	Analysis of scenarios, following the IPCC 2006 Guidelines.	Yes (64 - 12.8 - 3.7 Mt CO_2-eq/yr)	Russia	This landfill-based solution emits a lot of greenhouse gases (GHG). More than 3-% decrease could be achieved by recycling, incineration, and landfill gas recovery.
(Diemer et al., 2022)	France – construction waste	To assess the possible power of the circular economy when it comes to diminishing greenhouse gas discharges.	Both qualitative and quantitative evaluations.	✓	France	In the circular economy, reuse and recycling of the construction materials create an impact on reducing GHG.
(Zandieh et al., 2024)	United Kingdom	Examine how the waste sector fits in to the UK reaching its 2050 net-zero target, and look specifically at policies, technologies and the waste hierarchy.	Literature and policy review; analysis of options of waste treatment (WTE, AD, recycling) and its impact on circularity and carbon emissions.	✓ – Waste sector responsible for 3.7% of UK GHGs; landfill 70% of that.	UK	The traditional waste hierarchy is not enough it demands such things as the circular-economy measures, standardized sorting, and investments in new technologies regarding improved treatments. Waste-to-energy (WTE) and Anaerobic digestion (AD) technology have the potential of reducing greenhouse emissions up to 74% per compared to landfilling options in waste management.

Table 30. Waste Comparative Analysis of Regional / Asian Countries

Research Reference	Area of Research	Scope / Objective	Methodology	GHG Emissions Discussed	Country	Key Findings
(Ahmed et al., 2023)	Bangladesh (focus on Dhaka, ~7,000 tons waste/day)	Recommend an all-inclusive zero-waste structure that can wean it off landfill dependence and intensify recycling and collaboration between the municipal and privately owned sectors.	Conceptual framework, literature review and policy analysis.	✓	Bangladesh	Proactively promotes the 3Rs commitment (Reduce, Reuse, Recycle) and composting; reduces landfill methane emissions; prioritizes governance, stakeholder engagement and alignment with the Sustainable Development Goals (SDGs).
(Ullah et al., 2022)	Afghanistan – Kabul MSW	To assess the status quo in the urban solid waste (MSW) management in Kabul.	Case analysis, field survey, policy analysis	✓	Afghanistan	Kabul is dependent on open dumping, which has contributed a lot to greenhouse gas emissions. Recycling and waste-to-energy programs are needed to counter this problem.
(Meena et al., 2023)	India	Analyze the existing scenario on the generation, policies, challenges and opportunities of municipal solid waste (MSW), and provide some suggestions on the integrated solid waste management (ISWM) planning.	Narrative overview; gap analysis; SWOT analysis; and technology mapping (including composting, bio methanation, waste-to-energy (WTE) and incineration).	✓ – Discusses GHG emissions from MSW sector and estimation approaches.		Excessive municipal solid waste (MSW) and lax enforcement underline the importance of improved segregation, the 3Rs (Reduce, Reuse, Recycle), composting and bio methanation. There exists a great possibility of Waste to energy (WTE) projects and there is great need to have substantial reforms in ISWM at the Urban Local Body (ULB) level.

Table 31. Waste Comparative Analysis of Developing Economies

Research Reference	Area of Research	Scope / Objective	Methodology	GHG Emissions Discussed	Country	Key Findings
(Paes et al., 2020)	Brazil – MSW eco-efficiency	To evaluate eco-efficiency of management of Brazilian municipal solid waste (MSW) and GHG mitigation contribution.	Eco-efficiency analysis of case study.	✓	Brazil	Eco-efficient solid waste management (SWM) which consists of recycling, composting, energy recovery, and landfill gas capture will help to curb GHG.
	Brazil – WtE in MSW	To study the importance of WtE in eliminating the dependency on landfills and limiting GHG.	Case Study and Policy Analysis	✓	Brazil	WtE avoids emission of methane into the atmosphere that would have been emitted in landfills and promotes a more diversified energy pool.
(Zhang et al., 2024)	Shenzhen, China	Project MSW treatment and GHG emissions that will be generated under different policy scenarios throughout 2020-2030.	CWFM uses LSTM, GRU, and Bi-LSTM; a scenario analysis of incineration, landfill, and anaerobic digestion are used.	✓ Explicit focus; quantifies GHG emissions under different treatment mixes.	China	Monetary total emissions are the lowest in scenario 3, equaling about 5.91 Mt in 2030, which consists of 58% in incineration, two percent in landfill, and 40% AD. This shows that the best option is to augment AD and minimize the use of the landfill.
	China – MSW the technologies	To compare GHG emissions total of various MSW management alternatives.	To compare the overall GHG emissions of different MSW management alternatives.	✓	China	In landfills, the production of methane is the largest, but incineration with energy recovery gives maximum reductions in greenhouse gas emissions.
(Tinmaz & Demir, 2006)	Türkiye	Scenario simulation on solid waste	Emission factors and energy models	✓	Turkey	Incineration can lower emissions of carbon dioxide equivalent by up to 652,626 metric tons a year.
	Türkiye (national perspective)	Consider the possibility of MSW to be converted into biomass energy in order to have a circular economy.	Life Cycle Assessment (LCA) – is a comparison among landfill, recycling and biomass energy recovery.	SimaPro software		Recovery of biomass energy limits GHG emissions resulting in landfills and contributes towards a circular economy, as an alternative source of fuel that replaces fossil fuels. It is used best when coupled with recycling.

Table 32. Takeaways from Current Literature to Fill the Gaps in Knowledge

Current literature	**Gaps in knowledge**	**Proposal to address the gaps in knowledge (this study)**
Pakistan generates 49 million t/y (87,000 t/d) with 2.4% annual growth rate (Switch-Asia, n.d).	30-40% uncollected waste. Disposal method: waste burning and open disposal without resource recovery	SWM policy formation, waste diversion from open disposal for resource/ material recovery.
15 times increase in CH_4 level at Lakhodair, Lahore since 2015 (Toha et al., 2025).	Open disposal of waste without material recovery.	Waste diversion strategies to sustain the sector.
The share of waste sector is 32 Mt CO2-eq. (6%) in total GHG emissions (all sectors) in Pakistan (GOP, 2025).	Open disposal without waste diversion and LFG recovery.	Proposal for waste diversion to align the sector with the targets of NDCs
17% emissions reduction targets defined for waste sector in revised (GOP, 2025).	Province wise waste sector emissions inventory is missing.	This study is perfectly aligned with priority areas of NDC 3.0 (National SWM policy 2025-35) and also help in setting targets
Pakistan policy guidelines for trading in Carbon Market (GOP, 2024).	Sectoral targets are not defined.	This study will help in defining sectoral targets with Carbon Credit potential

Table 33. Parameters for Chemical Analysis of MSW

SN	**Proximate Analysis**	**Method**
1	Total Moisture Content	Based on ASTM D 3302/D3302M-19, D 3173-17a
2	Inherent Moisture	Based on ASTM D 3302/D3302M-19, D 3173-17a
3	Volatile Matter	Based on ASTM D 7582-15, ASTM D3175-20
4	Fixed Carbon	Based on ASTM D 3172-13 (2021) e1 / ASTM D 7582-15
5	Ash Content	Based on ASTM D3174-12(2018) / ASTM D 7582-15
6	Gross Calorific Value	Based on ASTM D5865 / D5865M-19
7	Total Sulfur	Based on ASTM D 4239-18e1
-	**Ultimate Analysis**	**Method**
1	Carbon (C)	Based on ASTM D 5373-21
2	Hydrogen (H)	Based on ASTM D 5373-21
3	Nitrogen (N)	Based on ASTM D 5373-21
4	Oxygen (O)	Based on ASTM D3176-15

Table 34: Punjab MSW Data for Emissions Calculation

NAME OF ADMINISTRATIVE UNIT	Population (2025)	WGR	Daily waste generation (t/d)	Daily collected waste (t/d)	Fuel l/t	Daily fuel consumption (l/d)	Daily diesel (l/d)	Daily gasoline (l/d)	Daily diesel at TCP (l/d)	Daily diesel at LFS (l/d)	Daily energy consumption at LFS kWh/d
BAHAWALNAGAR DISTRICT	3766194	0.38	1450	1160	3.49	4048	3239	809.7	1740	928.0	116
RURAL	2654343	0.32	849	680	3.49	2371	1897	474.3	1019	543.6	68.0
URBAN	1133107	0.45	510	408	3.49	1424	1139	284.7	612	326.3	40.8
BAHAWALPUR DISTRICT	4513030	0.38	1738	1390	3.49	4851	3881	970.2	2085	1112.0	139
RURAL	2724509	0.32	872	697	3.49	2434	1947	486.8	1046	558.0	69.7
URBAN	1804026	0.45	812	649	3.49	2267	1813	453.3	974	519.6	64.9
RAHIM YAR KHAN DISTRICT	5843409	0.38	2250	1800	3.49	6281	5025	1256.2	2700	1439.8	180
RURAL	4382849	0.32	1403	1122	3.49	3916	3133	783.2	1683	897.6	112.2
URBAN	1465996	0.45	660	528	3.49	1842	1474	368.4	792	422.2	52.8
DE**RA GHAZI KHAN DISTRICT**	3588158	0.38	1381	1105	3.49	3857	3086	771.4	1658	884.1	110.5
RURAL	2679478	0.32	857	686	3.49	2394	1915	478.8	1029	548.8	68.6
URBAN	920080	0.45	414	331	3.49	1156	925	231.2	497	265.0	33.1
LAYYAH DISTRICT	2204610	0.38	849	679	3.49	2370	1896	474.0	1019	543.2	67.9
RURAL	1793942	0.32	574	459	3.49	1603	1282	320.6	689	367.4	45.9
URBAN	410865	0.45	185	148	3.49	516	413	103.2	222	118.3	14.8
MUZAFFARGARH DISTRICT	5268371	0.38	2028	1623	3.49	5663	4530	1132.6	2434	1298	162.3
RURAL	4226566	0.32	1353	1082	3.49	3776	3021	755.2	1623	865.6	108.2
URBAN	1048152	0.45	472	377	3.49	1317	1054	263.4	566	301.9	37.7
RAJANPUR DISTRICT	2525639	0.38	972	778	3.49	2715	2172	543.0	1167	622.3	77.8
RURAL	1781372	0.32	570	456	3.49	1592	1273	318.3	684	364.8	45.6
URBAN	778314	0.45	350	280	3.49	978	782	195.6	420	224.2	28.0
CHINIOT DISTRICT	1633961	0.38	629	503	3.49	1756	1405	351.3	755	402.6	50.3
RURAL	1116682	0.32	357	286	3.49	998	798	199.5	429	228.7	28.6
URBAN	517342	0.45	233	186	3.49	650	520	130.0	279	149.0	18.6
FAISALABAD DISTRICT	9513712	0.38	3663	2930	3.49	10226	8181	2045.3	4395	2344.2	293.0
RURAL	4889375	0.32	1565	1252	3.49	4368	3495	873.7	1878	1001.3	125.2
URBAN	4624659	0.45	2081	1665	3.49	5810	4648	1162.1	2497	1331.9	166.5
JHANG DISTRICT	3181527	0.38	1225	980	3.49	3420	2736	684.0	1470	783.9	98
RURAL	2306165	0.32	738	590	3.49	2060	1648	412.1	886	472.3	59
URBAN	882877	0.45	397	318	3.49	1109	887	221.8	477	254.3	31.8

TOBA TEK SINGH DISTRICT	2646453	0.38	1019	815	3.49	2845	2276	568.9	1223	652.1	81.5
RURAL	2036920	0.32	652	521	3.49	1820	1456	364.0	782	417.2	52.1
URBAN	611199	0.45	275	220	3.49	768	614	153.6	330	176.0	22
GUJRANWALA DISTRICT	6315330	0.38	2431	1945	3.49	6788	5431	1357.7	2918	1556	194.5
RURAL	2477008	0.32	793	634	3.49	2213	1770	442.6	951	507.3	63.4
URBAN	3839551	0.45	1728	1382	3.49	4824	3859	964.8	2073	1105	138.2
GUJRAT DISTRICT	3390903	0.38	1305	1044	3.49	3645	2916	729.0	1567	835.5	104.4
RURAL	1883986	0.32	603	482	3.49	1683	1347	336.6	723	385.8	48.2
URBAN	1549636	0.45	697	558	3.49	1947	1558	389.4	837	446.3	55.8
HAFIZABAD DISTRICT	1379343	0.38	531	425	3.49	1483	1186	296.5	637	339.9	42.5
RURAL	837111	0.32	268	214	3.49	748	598	149.6	321	171.4	21.4
URBAN	543787	0.45	245	196	3.49	683	547	136.6	294	156.6	19.6
MANDI BAHAUDDIN DISTRICT	1915698	0.38	738	590	3.49	2059	1647	411.8	885	472.0	59.0
RURAL	1563322	0.32	500	400	3.49	1397	1117	279.3	600	320.2	40.0
URBAN	353017	0.45	159	127	3.49	444	355	88.7	191	101.7	12.7
NAROWAL DISTRICT	2039806	0.38	785	628	3.49	2193	1754	438.5	942	502.6	62.8
RURAL	1655734	0.32	530	424	3.49	1479	1183	295.9	636	339.1	42.4
URBAN	386897	0.45	174	139	3.49	486	389	97.2	209	111.4	13.9
SIALKOT DISTRICT	4721671	0.38	1818	1454	3.49	5075	4060	1015.1	2181	1163.4	145.4
RURAL	3112338	0.32	996	797	3.49	2781	2225	556.1	1195	637.4	79.7
URBAN	1615640	0.45	727	582	3.49	2030	1624	406.0	872	465.3	58.2
KASUR DISTRICT	4319268	0.38	1663	1330	3.49	4643	3714	928.6	1996	1064	133.0
RURAL	2939244	0.32	941	752	3.49	2626	2101	525.2	1129	602.0	75.2
URBAN	1390746	0.45	626	501	3.49	1747	1398	349.5	751	400.5	50.1
LAHORE DISTRICT	13702588	0.54	7399	5920	3.49	20659	16527	4131.8	8879	4735	592.0
RURAL	0	0	0	0	3.49	0	0	0.0	0	0.0	0.0
URBAN	13702588	0.54	7399	5920	3.49	20659	16527	4131.8	8879	4735	592.0
NANKANA SAHIB DISTRICT	1740768	0.38	670	536	3.49	1871	1497	374.2	804	428.9	53.6
RURAL	1386735	0.32	444	355	3.49	1239	991	247.8	533	284.0	35.5
URBAN	354770	0.45	160	128	3.49	446	357	89.1	192	102.2	12.8
SHEIKHUPURA DISTRICT	4268025	0.38	1643	1315	3.49	4588	3670	917.6	1972	1051	131.5
RURAL	2584453	0.32	827	662	3.49	2309	1847	461.8	992	529.3	66.2
URBAN	1688872	0.45	760	608	3.49	2122	1698	424.4	912	486.4	60.8
KHANEWAL DISTRICT	3526995	0.38	1358	1086	3.49	3791	3033	758.2	1629	869.1	108.6
RURAL	2761198	0.32	884	707	3.49	2467	1974	493.4	1060	565.5	70.7

URBAN	766525	0.45	345	276	3.49	963	770	192.6	414	220.8	27.6
LODHRAN DISTRICT	2011372	0.38	774	620	3.49	2162	1730	432.4	929	495.6	62.0
RURAL	1664123	0.32	533	426	3.49	1487	1189	297.4	639	340.8	42.6
URBAN	347757	0.45	156	125	3.49	437	350	87.4	188	100.2	12.5
MULTAN DISTRICT	5585595	0.38	2150	1720	3.49	6004	4803	1200.8	2581	1376	172.0
RURAL	2923501	0.32	936	748	3.49	2612	2090	522.4	1123	598.7	74.8
URBAN	2667394	0.45	1200	960	3.49	3351	2681	670.3	1440	768.2	96.0
VEHARI DISTRICT	3627658	0.38	1397	1117	3.49	3899	3120	779.9	1676	893.9	111.7
RURAL	2737345	0.32	876	701	3.49	2446	1957	489.1	1051	560.6	70.1
URBAN	905813	0.45	408	326	3.49	1138	910	227.6	489	260.9	32.6
ATTOCK DISTRICT	2274601	0.38	876	701	3.49	2445	1956	489.0	1051	560.5	70.1
RURAL	1600458	0.32	512	410	3.49	1430	1144	286.0	615	327.8	41.0
URBAN	676072	0.45	304	243	3.49	849	680	169.9	365	194.7	24.3
CHAKWAL DISTRICT	1823130	0.38	702	562	3.49	1960	1568	391.9	842	449.2	56.2
RURAL	1330936	0.32	426	341	3.49	1189	951	237.8	511	272.6	34.1
URBAN	501560	0.45	226	181	3.49	630	504	126.0	271	144.4	18.1
JHELUM DISTRICT	1440291	0.38	555	444	3.49	1548	1239	309.6	665	354.9	44.4
RURAL	832117	0.32	266	213	3.49	743	595	148.7	320	170.4	21.3
URBAN	623709	0.45	281	225	3.49	784	627	156.7	337	179.6	22.5
RAWALPINDI DISTRICT	6379008	0.38	2456	1965	3.49	6857	5486	1371.4	2947	1571	196.5
RURAL	1768138	0.32	566	453	3.49	1580	1264	315.9	679	362.1	45.3
URBAN	4713051	0.45	2121	1697	3.49	5921	4737	1184.3	2545	1357	169.7
OKARA DISTRICT	3690128	0.38	1421	1137	3.49	3967	3173	793.3	1705	909.2	113.7
RURAL	2373031	0.32	759	607	3.49	2120	1696	424.0	911	486.0	60.7
URBAN	1331829	0.45	599	479	3.49	1673	1339	334.7	719	383.6	47.9
PAKPATTAN DISTRICT	2251908	0.38	867	694	3.49	2421	1936	484.1	1040	554.9	69.4
RURAL	1708849	0.32	547	437	3.49	1527	1221	305.4	656	350.0	43.7
URBAN	557007	0.45	251	201	3.49	700	560	140.0	301	160.4	20.1
SAHIWAL DISTRICT	3016779	0.38	1161	929	3.49	3243	2594	648.6	1394	743.3	92.9
RURAL	2168352	0.32	694	555	3.49	1937	1550	387.5	833	444.1	55.5
URBAN	861592	0.45	388	310	3.49	1083	866	216.5	465	248.1	31.0
BHAKKAR DISTRICT	2073428	0.38	798	639	3.49	2229	1783	445.8	958	510.9	63.9
RURAL	1684820	0.32	539	431	3.49	1505	1204	301.1	647	345.1	43.1
URBAN	390325	0.45	176	141	3.49	490	392	98.1	211	112.4	14.1
KHUSHAB DISTRICT	1583044	0.38	609	488	3.49	1702	1361	340.3	731	390.1	48.8

RURAL	1139701	0.32	365	292	3.49	1018	815	203.7	438	233.4	29.2
URBAN	443362	0.45	200	160	3.49	557	446	111.4	239	127.7	16.0
MIANWALI DISTRICT	1892847	0.38	729	583	3.49	2035	1628	406.9	874	466.4	58.3
RURAL	1516911	0.32	485	388	3.49	1355	1084	271.1	582	310.7	38.8
URBAN	376210	0.45	169	135	3.49	473	378	94.5	203	108.3	13.5
SARGODHA DISTRICT	4571470	0.38	1760	1408	3.49	4914	3931	982.8	2112	1126	140.8
RURAL	2765075	0.32	885	708	3.49	2470	1976	494.1	1062	566.3	70.8
URBAN	1834584	0.45	826	660	3.49	2305	1844	461.0	991	528.4	66.0

Table 35. Sindh MSW Data for Emissions Calculation

NAME OF ADMINISTRATIVE UNIT	Population (2025)	WGR	Daily waste generation (t/d)	Daily collected waste (t/d)	Fuel l/t	Daily fuel consumption (l/d)	Daily diesel (l/d)	Daily gasoline (l/d)	Daily diesel at TCP (l/d)	Daily diesel at LFS (l/d)	Daily energy consumption at LFS kWh/d	Collection Efficiency (%)
BADIN DISTRICT	1,997,038	0.44	834	314	3.49	1,097	877	219	471	251	31	37.7
RURAL	1,553,166	0.4	621	186	3.49	650	520	130	280	149	19	30.0
URBAN	443,926	0.48	213	128	3.49	446	357	89	192	102	13	60.0
DADU DISTRICT	1,811,631	0.44	761	295	3.49	1,028	822	206	442	236	29	38.7
RURAL	1,352,306	0.4	541	162	3.49	566	453	113	243	130	16	30.0
URBAN	459,372	0.48	220	132	3.49	462	369	92	198	106	13	60.0
HYDERABAD DISTRICT	2,515,651	0.44	1174	754	3.49	2,631	2,105	526	1,131	603	75	64.2
RURAL	423,234	0.4	169	51	3.49	177	142	35	76	41	5	30.0
URBAN	2,092,421	0.48	1004	703	3.49	2,454	1,963	491	1055	562	70	70.0
JAMSHORO DISTRICT	1,161,881	0.44	510	233	3.49	813	650	163	349	186	23	45.7
RURAL	607,479	0.4	243	73	3.49	254	204	51	109	58	7	30.0
URBAN	555,457	0.48	267	160	3.49	558	447	112	240	128	16	60.0
MATIARI DISTRICT	877,686	0.44	368	131	3.49	455	364	91	196	104	13	35.5
RURAL	667,852	0.4	267	80	3.49	280	224	56	120	64	8	30.0
URBAN	209,836	0.48	101	50	3.49	176	141	35	76	40	5	50.0
SUJAWAL DISTRICT	860,445	0.44	351	114	3.49	398	318	80	171	91	11	32.5
RURAL	770,478	0.4	308	92	3.49	323	258	65	139	74	9	30.0
URBAN	89,996	0.48	43	22	3.49	75	60	15	32	17	2	50.0
TANDO ALLAHYAR DISTRICT	951,731	0.44	404	163	3.49	570	456	114	245	131	16	40.4
RURAL	660,007	0.4	264	79	3.49	276	221	55	119	63	8	30.0
URBAN	291,819	0.48	140	84	3.49	293	235	59	126	67	8	60.0
TANDO MUHAMMAD KHAN DISTRICT	743,283	0.44	311	110	3.49	382	306	76	164	88	11	35.2
RURAL	573,986	0.4	230	69	3.49	240	192	48	103	55	7	30.0
URBAN	169,478	0.48	81	41	3.49	142	114	28	61	33	4	50.0
THATTA DISTRICT	1,119,235	0.44	464	158	3.49	552	442	110	237	127	16	34.1
RURAL	919,441	0.4	368	110	3.49	385	308	77	165	88	11	30.0
URBAN	199,795	0.48	96	48	3.49	167	134	33	72	38	5	50.0
KARACHI CENTRAL DISTRICT	4,157,993	0.6	2495	1871	3.49	6,530	5,224	1,306	2,807	1,497	187	75.0
RURAL	-	0.4	0	0	0	-	-	-	0	0	0	0.0
URBAN	4,157,993	0.6	2495	1871	3.49	6,530	5,224	1,306	2807	1497	187	75.0

KARACHI EAST DISTRICT	4,350,441	0.6	2610	1958	3.49	6,832	5,466	1,366	2,937	1,566	196	75.0
RURAL	-	0.4	0	0	3.49	-	-	-	0	0	0	0.0
URBAN	4,350,441	0.6	2610	1958	3.49	6,832	5,466	1,366	2937	1566	196	75.0
KARACHI SOUTH DISTRICT	2,554,251	0.6	1533	1149	3.49	4,011	3,209	802	1,724	920	115	75.0
RURAL	-	0.4	0	0	3.49	-	-	-	0	0	0	0.0
URBAN	2,554,251	0.6	1533	1149	3.49	4,011	3,209	802	1724	920	115	75.0
KARACHI WEST DISTRICT	2,917,328	0.5	1694	1242	3.49	4,334	3,467	867	1,863	993	124	73.3
RURAL	288,052	0.4	115	58	3.49	201	161	40	86	46	6	50.0
URBAN	2,631,368	0.6	1579	1184	3.49	4,133	3,306	827	1776	947	118	75.0
KEAMARI DISTRICT	2,154,954	0.6	1323	992	3.49	3,463	2,771	693	1,489	794	99	75.0
RURAL	-	0.4	0	0	3.49	-	-	-	0	0	0	0.0
URBAN	2,205,211	0.6	1323	992	3.49	3,463	2,771	693	1489	794	99	75.0
KORANGI DISTRICT	3,338,434	0.5	2003	1502	3.49	5,243	4,194	1,049	2,253	1,202	150	75.0
RURAL	-	0.4	0	0	3.49	-	-	-	0	0	0	0.0
URBAN	3,338,434	0.6	2003	1502	3.49	5,243	4,194	1,049	2253	1202	150	75.0
MALIR DISTRICT	2,630,322	0.5	1298	829	3.49	2,894	2,315	579	1,244	663	83	63.9
RURAL	1,441,860	0.4	577	288	3.49	1,006	805	201	433	231	29	50.0
URBAN	1,201,674	0.6	721	541	3.49	1,887	1,510	377	811	433	54	75.0
JACOBABAD DISTRICT	1,235,914	0.44	525	213	3.49	744	595	149	320	171	21	40.6
RURAL	849,597	0.4	340	102	3.49	356	285	71	153	82	10	30.0
URBAN	386,543	0.48	186	111	3.49	389	311	78	167	89	11	60.0
KAMBAR SHAHDAD KOT DISTRICT	1,579,041	0.44	666	262	3.49	914	731	183	393	210	26	39.3
RURAL	1,149,007	0.4	460	138	3.49	481	385	96	207	110	14	30.0
URBAN	430,590	0.48	207	124	3.49	433	346	87	186	99	12	60.0
KASHMORE DISTRICT	1,286,063	0.44	537	201	3.49	702	561	140	302	161	20	37.5
RURAL	1,008,188	0.4	403	121	3.49	422	338	84	181	97	12	30.0
URBAN	278,124	0.48	133	80	3.49	280	224	56	120	64	8	60.0
LARKANA DISTRICT	1,881,996	0.44	820	366	3.49	1,277	1,022	255	549	293	37	44.7
RURAL	1,047,864	0.4	419	126	3.49	439	351	88	189	101	13	30.0
URBAN	834,375	0.48	401	240	3.49	839	671	168	360	192	24	60.0
SHIKARPUR DISTRICT	1,441,423	0.44	603	227	3.49	794	635	159	341	182	23	37.7
RURAL	1,118,254	0.4	447	134	3.49	468	375	94	201	107	13	30.0
URBAN	323,665	0.48	155	93	3.49	325	260	65	140	75	9	60.0
MIRPUR KHAS DISTRICT	1,745,055	0.44	739	296	3.49	1,032	825	206	443	237	30	40.0
RURAL	1,231,810	0.4	493	148	3.49	516	413	103	222	118	15	30.0

URBAN	513,278	0.48	246	148	3.49	516	413	103	222	118	15	60.0
THARPARKAR DISTRICT	1,824,614	0.44	742	237	3.49	826	661	165	355	189	24	31.9
RURAL	1,676,011	0.4	670	201	3.49	702	562	140	302	161	20	30.0
URBAN	148,605	0.48	71	36	3.49	124	100	25	53	29	4	50.0
UMER KOT DISTRICT	1,190,220	0.44	497	187	3.49	653	523	131	281	150	19	37.7
RURAL	926,048	0.4	370	111	3.49	388	310	78	167	89	11	30.0
URBAN	264,192	0.48	127	76	3.49	266	212	53	114	61	8	60.0
NAUSHAHRO FEROZE DISTRICT	1,835,930	0.44	781	315	3.49	1,099	879	220	472	252	31	40.3
RURAL	1,282,459	0.4	513	154	3.49	537	430	107	231	123	15	30.0
URBAN	559,031	0.48	268	161	3.49	562	450	112	242	129	16	60.0
SANGHAR DISTRICT	2,401,979	0.44	1013	398	3.49	1,388	1,111	278	597	318	40	39.3
RURAL	1,750,210	0.4	700	210	3.49	733	586	147	315	168	21	30.0
URBAN	651,854	0.48	313	188	3.49	655	524	131	282	150	19	60.0
SHAHEED BENAZIRABAD DISTRICT	1,929,702	0.44	823	339	3.49	1,183	947	237	509	271	34	41.2
RURAL	1,291,136	0.4	516	155	3.49	541	433	108	232	124	15	30.0
URBAN	639,422	0.48	307	184	3.49	643	514	129	276	147	18	60.0
GHOTKI DISTRICT	1,816,065	0.44	757	283	3.49	987	789	197	424	226	28	37.3
RURAL	1,430,324	0.4	572	172	3.49	599	479	120	257	137	17	30.0
URBAN	385,796	0.48	185	111	3.49	388	310	78	167	89	11	60.0
KHAIRPUR DISTRICT	2,665,197	0.44	1136	466	3.49	1,625	1,300	325	698	373	47	41.0
RURAL	1,797,190	0.4	719	216	3.49	753	602	151	323	173	22	30.0
URBAN	868,017	0.48	417	250	3.49	872	698	174	375	200	25	60.0
SUKKUR DISTRICT	1,693,909	0.44	746	346	3.49	1,207	966	241	519	277	35	46.4
RURAL	845,001	0.4	338	101	3.49	354	283	71	152	81	10	30.0
URBAN	849,152	0.48	408	245	3.49	853	683	171	367	196	24	60.0

Table 36. KPK MSW Data for Emissions Calculation

NAME OF ADMINISTRATIVE UNIT	Population (2025)	WGR	Daily waste generation (t/d)	Daily collected waste (t/d)	Fuel l/t	Daily fuel consumption (l/d)	Daily diesel (l/d)	Daily gasoline (l/d)	Daily diesel at TCP (l/d)	Daily diesel at LFS (l/d)	Daily energy consumption at LFS kWh/d	Collection efficiency (%)
ABBOTTABAD DISTRICT	1,449,031	0.38	558	199	7	696	557	139	299	160	20	36
RURAL	1,103,167	0.32	353	106	3.49	370	296	74	159	85	11	30
URBAN	346,210	0.45	156	93	3.49	326	261	65	140	75	9	60
BAJAUR DISTRICT	1,361,432	0.38	524	131	3.49	456	365	91	196	105	13	30
RURAL	1,361,432	0.32	436	131	3.49	456	365	91	196	105	13	30
BANNU DISTRICT	1,411,177	0.38	543	142	7	494	396	99	213	113	14	26
RURAL	1,363,546	0.32	436	131	3.49	457	365	91	196	105	13	30
URBAN	47,891	0.45	22	11	3.49	38	30	8	16	9	1	50
BATAGRAM DISTRICT	582,705	0.38	224	56	7	195	156	39	84	45	6	25
RURAL	582,705	0.32	186	56	3.49	195	156	39	84	45	6	30
BUNER DISTRICT	1,061,016	0.38	408	102	7	355	284	71	153	81	10	25
RURAL	1,061,016	0.32	340	102	3.49	355	284	71	153	81	10	30
CHARSADDA DISTRICT	1,917,332	0.38	738	236	7	825	660	165	354	189	24	32
RURAL	1,617,297	0.32	518	155	3.49	542	433	108	233	124	16	30
URBAN	300,254	0.45	135	81	3.49	283	226	57	122	65	8	60
DERA ISMAIL KHAN DISTRICT	1,877,742	0.38	723	246	7	860	688	172	370	197	25	34
RURAL	1,498,152	0.32	479	144	3.49	502	402	100	216	115	14	30
URBAN	379,746	0.45	171	103	3.49	358	286	72	154	82	10	60
HANGU DISTRICT	532,318	0.38	205	62	7	215	172	43	92	49	6	30
RURAL	452,536	0.32	145	43	3.49	152	121	30	65	35	4	30
URBAN	80,756	0.45	36	18	3.49	63	51	13	27	15	2	50
HARIPUR DISTRICT	1,239,142	0.38	477	139	7	484	387	97	208	111	14	29
RURAL	1,086,246	0.32	348	104	3.49	364	291	73	156	83	10	30
URBAN	153,019	0.45	69	34	3.49	120	96	24	52	28	3	50
KARAK DISTRICT	856,553	0.38	330	90	7	314	251	63	135	72	9	27
RURAL	795,953	0.32	255	76	3.49	267	213	53	115	61	8	30
URBAN	60,604	0.45	27	14	3.49	48	38	10	20	11	1	50
KHYBER DISTRICT	1,206,166	0.38	464	128	7	447	357	89	192	102	13	28
RURAL	1,113,199	0.32	356	107	3.49	373	298	75	160	85	11	30
URBAN	93,805	0.45	42	21	3.49	74	59	15	32	17	2	50
KOHAT DISTRICT	1,278,889	0.38	492	172	7	600	480	120	258	137	17	35
RURAL	997,598	0.32	319	96	3.49	334	267	67	144	77	10	30
URBAN	281,751	0.45	127	76	3.49	265	212	53	114	61	8	60
KOLAI PALAS KOHISTAN DISTRICT	281,935	0.38	109	27	7	94	76	19	41	22	3	25

RURAL	281,935	0.32	90	27	3.49	94	76	19	41	22	3	30
KURRAM DISTRICT	852,178	0.38	328	88	7	307	246	61	132	70	9	27
RURAL	803,966	0.32	257	77	3.49	269	215	54	116	62	8	30
URBAN	48,263	0.45	22	11	3.49	38	30	8	16	9	1	50
LAKKI MARWAT DISTRICT	1,091,826	0.38	420	189	7	659	527	132	283	151	19	45
RURAL	983,649	0.32	315	94	3.49	330	264	66	142	76	9	30
URBAN	108,177	0.45	49	24	3.49	85	68	17	37	19	2	50
LOWER CHITRAL DISTRICT	335,846	0.38	129	40	7	139	112	28	60	32	4	31
RURAL	275,987	0.32	88	26	3.49	92	74	18	40	21	3	30
URBAN	59,859	0.45	27	13	3.49	47	38	9	20	11	1	50
LOWER DIR DISTRICT	1,728,641	0.38	666	172	7	602	482	120	259	138	17	26
RURAL	1,677,968	0.32	537	161	3.49	562	450	112	242	129	16	30
URBAN	50,685	0.45	23	11	3.49	40	32	8	17	9	1	50
LOWER KOHISTAN DISTRICT	404,324	0.38	156	39	7	135	108	27	58	31	4	25
RURAL	404,324	0.32	129	39	3.49	135	108	27	58	31	4	30
MALAKAND DISTRICT	866,035	0.385	333	93	7	324	259	65	139	74	9	28
RURAL	790,513	0.32	253	76	3.49	265	212	53	114	61	8	30
URBAN	75,587	0.45	34	17	3.49	59	47	12	26	14	2	50
MANSEHRA DISTRICT	1,885,960	0.38	726	201	7	703	563	141	302	161	20	28
RURAL	1,727,902	0.32	553	166	3.49	579	463	116	249	133	17	30
URBAN	158,305	0.45	71	36	3.49	124	99	25	53	28	4	50
MARDAN DISTRICT	2,881,613	0.38	1,109	356	7	1244	995	249	535	285	36	32
RURAL	2,425,591	0.32	776	233	3.49	813	650	163	349	186	23	30
URBAN	457,814	0.45	206	124	3.49	431	345	86	185	99	12	60
MOHMAND DISTRICT	583,409	0.38	225	56	7	195	156	39	84	45	6	25
RURAL	583,409	0.32	187	56	3.49	195	156	39	84	45	6	30
NORTH WAZIRISTAN DISTRICT	753,488	0.38	290	73	7	254	203	51	109	58	7	25
RURAL	749,532	0.32	240	72	3.49	251	201	50	108	58	7	30
URBAN	4,056	0.45	2	1	3.49	3	3	1	1	1	0	50
NOWSHERA DISTRICT	1,821,005	0.38	701	235	7	819	655	164	352	188	23	33
RURAL	1,479,946	0.32	474	142	3.49	496	397	99	213	114	14	30
URBAN	342,773	0.45	154	93	3.49	323	258	65	139	74	9	60
ORAKZAI DISTRICT	446,173	0.38	172	43	7	149	120	30	64	34	4	25
RURAL	446,173	0.32	143	43	3.49	149	120	30	64	34	4	30
PESHAWAR DISTRICT	4,910,599	0.38	1,891	886	7	3090	2472	618	1328	708	89	47
RURAL	3,038,545	0.32	972	292	3.49	1018	814	204	438	233	29	30
URBAN	1,885,099	0.45	848	594	3.49	2072	1658	414	891	475	59	70

SHANGLA DISTRICT	940,158	0.38	362	90	7	315	252	63	135	72	9	25
RURAL	940,158	0.32	301	90	3.49	315	252	63	135	72	9	30
SOUTH WAZIRISTAN DISTRICT	974,134	0.38	375	94	7	326	261	65	140	75	9	25
RURAL	974,134	0.32	312	94	3.49	326	261	65	140	75	9	30
SWABI DISTRICT	1,994,147	0.38	768	255	7	889	711	178	382	204	25	33
RURAL	1,630,340	0.32	522	157	3.49	546	437	109	235	125	16	30
URBAN	364,089	0.45	164	98	3.49	343	274	69	147	79	10	60
SWAT DISTRICT	2,827,367	0.38	1,089	416	7	1452	1161	290	624	333	42	38
RURAL	1,997,141	0.32	639	192	3.49	669	535	134	288	153	19	30
URBAN	830,327	0.45	374	224	3.49	782	626	156	336	179	22	60
TANK DISTRICT	485,704	0.38	187	53	7	185	148	37	80	42	5	28
RURAL	435,843	0.32	139	42	3.49	146	117	29	63	33	4	30
URBAN	49,897	0.45	22	11	3.49	39	31	8	17	9	1	50
TORGHAR DISTRICT	211,233	0.38	81	20	7	71	57	14	30	16	2	25
RURAL	211,233	0.32	68	20	3.49	71	57	14	30	16	2	30
UPPER CHITRAL DISTRICT	205,173	0.38	79	20	7	69	55	14	30	16	2	25
RURAL	205,173	0.32	66	20	3.49	69	55	14	30	16	2	30
UPPER DIR DISTRICT	1,133,311	0.38	436	115	7	402	321	80	173	92	12	26
RURAL	1,084,182	0.32	347	104	3.49	363	291	73	156	83	10	30
URBAN	49,162	0.45	22	11	3.49	39	31	8	17	9	1	50
UPPER KOHISTAN DISTRICT	470,609	0.38	181	45	7	158	126	32	68	36	5	25
RURAL	470,609	0.32	151	45	3.49	158	126	32	68	36	5	30

Table 37. Balochistan MSW Data for Emissions Calculation

NAME OF ADMINISTRATIVE UNIT	Population (2025)	WGR	Daily waste generation (t/d)	Daily collected waste (t/d)	Fuel l/t	Daily fuel consumption (l/d)	Daily diesel (l/d)	Daily gasoline (l/d)	Daily diesel at TCP (l/d)	Collection efficiency (%)
AWARAN DISTRICT	203,507	0.46	94	32	7	112	90	22	26	34
RURAL	151,585	0.42	64	19	3.49	67	53	13	15	30
URBAN	52,007	0.5	26	13	3.49	45	36	9	10	50
KALAT DISTRICT	299,020	0.46	138	39	7	136	108	27	31	28
RURAL	251,821	0.42	106	32	3.49	111	89	22	25	30
URBAN	47,334	0.5	24	7	3.49	25	20	5	6	30
KHUZDAR DISTRICT	1,073,929	0.46	494	205	7	715	572	143	164	41
RURAL	674,413	0.42	283	85	3.49	297	237	59	68	30
URBAN	399,946	0.5	200	120	3.49	419	335	84	96	60
LASBELA DISTRICT	720,057	0.46	331	151	7	528	423	106	121	46
RURAL	371,400	0.42	156	47	3.49	163	131	33	37	30
URBAN	348,666	0.5	174	105	3.49	365	292	73	84	60
MASTUNG DISTRICT	331,010	0.46	152	43	7	149	119	30	34	28
RURAL	288,666	0.42	121	36	3.49	127	102	25	29	30
URBAN	42,350	0.5	21	6	3.49	22	18	4	5	30
SURAB DISTRICT	307,588	0.46	141	40	7	139	111	28	32	28
RURAL	271,637	0.42	114	34	3.49	119	96	24	27	30
URBAN	36,764	0.5	18	6	3.49	19	15	4	4	30
BARKHAN DISTRICT	225,272	0.46	104	29	7	100	80	20	23	28
RURAL	210,022	0.42	88	26	3.49	92	74	18	21	30
URBAN	15,255	0.5	8	2	3.49	8	6	2	2	30
DUKI DISTRICT	226,136	0.46	104	29	7	100	80	20	23	28
RURAL	216,720	0.42	91	27	3.49	95	76	19	22	30
URBAN	9,698	0.5	5	1	3.49	5	4	1	1	30
LORALAI DISTRICT	282,483	0.46	130	52	7	129	103	26	30	40
RURAL	221,215	0.42	93	28	3.49	97	78	19	22	30
URBAN	61,279	0.5	31	9	3.49	32	26	6	7	30
MUSAKHEL DISTRICT	187,595	0.46	86	24	7	84	67	17	19	28
RURAL	171,191	0.42	72	22	3.49	75	60	15	17	30
URBAN	16,406	0.5	8	2	3.49	9	7	2	2	30

GWADAR DISTRICT	321,014	0.46	148	45	7	156	124	31	36	30
RURAL	165,067	0.42	69	21	3.49	73	58	15	17	30
URBAN	158,456	0.5	79	24	3.49	83	66	17	19	30
KECH DISTRICT	1,117,927	0.46	514	214	7	747	598	149	171	42
RURAL	699,107	0.42	294	88	3.49	307	246	61	70	30
URBAN	419,924	0.5	210	126	3.49	440	352	88	101	60
PANJGUR DISTRICT	598,553	0.46	275	80	7	281	225	56	64	29
RURAL	403,065	0.42	169	51	3.49	177	142	35	41	30
URBAN	197,505	0.5	99	30	3.49	103	83	21	24	30
JAFFARABAD DISTRICT	624,219	0.46	287	88	10	306	245	61	70	31
RURAL	459,562	0.42	193	58	3.49	202	162	40	46	30
URBAN	165,337	0.5	83	25	3.49	87	69	17	20	30
JHAL MAGSI DISTRICT	225,702	0.46	104	30	7	104	83	21	24	29
RURAL	194,167	0.42	82	24	3.49	85	68	17	20	30
URBAN	35,173	0.5	18	5	3.49	18	15	4	4	30
KACHHI DISTRICT	499,734	0.46	230	65	7	228	182	46	52	28
RURAL	406,238	0.42	171	51	3.49	179	143	36	41	30
URBAN	93,705	0.5	47	14	3.49	49	39	10	11	30
NASIRABAD DISTRICT	590,279	0.46	272	77	7	269	215	54	62	28
RURAL	479,555	0.42	201	60	3.49	211	169	42	48	30
URBAN	110,763	0.5	55	17	3.49	58	46	12	13	30
SOHBATPUR DISTRICT	255,049	0.46	117	33	7	113	91	23	26	28
RURAL	239,649	0.42	101	30	3.49	105	84	21	24	30
URBAN	15,408	0.5	8	2	3.49	8	6	2	2	30
CHAMAN DISTRICT	477,305	0.46	220	63	7	221	177	44	51	29
RURAL	344,773	0.42	145	43	3.49	152	121	30	35	30
URBAN	132,542	0.5	66	20	3.49	69	56	14	16	30
KILLA ABDULLAH DISTRICT	375,711	0.46	173	48	7	169	135	34	39	28
RURAL	336,866	0.42	141	42	3.49	148	119	30	34	30
URBAN	39,161	0.5	20	6	3.49	21	16	4	5	30
PISHIN DISTRICT	871,289	0.46	401	162	7	565	452	113	130	40
RURAL	590,894	0.42	248	74	3.49	260	208	52	60	30
URBAN	291,507	0.5	146	87	3.49	305	244	61	70	60
QUETTA DISTRICT	2,714,591	0.46	1,249	758	7	2644	2115	529	606	61
RURAL	960,266	0.42	403	121	3.49	422	338	84	97	30

URBAN	1,818,953	0.5	909	637	3.49	2222	1777	444	509	70
CHAGAI DISTRICT	285,179	0.46	131	36	7	127	102	25	29	28
RURAL	263,678	0.42	111	33	3.49	116	93	23	27	30
URBAN	21,508	0.5	11	3	3.49	11	9	2	3	30
KHARAN DISTRICT	304,611	0.46	140	41	7	142	113	28	33	29
RURAL	210,616	0.42	88	27	3.49	93	74	19	21	30
URBAN	94,005	0.5	47	14	3.49	49	39	10	11	30
NUSHKI DISTRICT	218,494	0.46	101	29	7	100	80	20	23	29
RURAL	169,341	0.42	71	21	3.49	74	60	15	17	30
URBAN	49,322	0.5	25	7	3.49	26	21	5	6	30
WASHUK DISTRICT	362,926	0.46	167	47	7	164	131	33	38	28
RURAL	312,236	0.42	131	39	3.49	137	110	27	31	30
URBAN	50,787	0.5	25	8	3.49	27	21	5	6	30
DERA BUGTI DISTRICT	370,597	0.46	170	49	7	172	138	34	40	29
RURAL	259,396	0.42	109	33	3.49	114	91	23	26	30
URBAN	111,291	0.5	56	17	3.49	58	47	12	13	30
HARNAI DISTRICT	139,779	0.46	64	19	7	65	52	13	15	29
RURAL	102,730	0.42	43	13	3.49	45	36	9	10	30
URBAN	37,063	0.5	19	6	3.49	19	16	4	4	30
KOHLU DISTRICT	277,826	0.46	128	35	7	124	99	25	28	28
RURAL	258,368	0.42	109	33	3.49	114	91	23	26	30
URBAN	19,521	0.5	10	3	3.49	10	8	2	2	30
SIBI DISTRICT	241,311	0.46	111	32	7	112	90	22	26	29
RURAL	171,000	0.42	72	22	3.49	75	60	15	17	30
URBAN	70,919	0.5	35	11	3.49	37	30	7	9	30
ZIARAT DISTRICT	200,537	0.46	92	35	7	123	98	25	28	38
RURAL	134,995	0.42	57	17	3.49	59	47	12	14	30
URBAN	120,940	0.5	60	18	3.49	63	51	13	15	30
KILLA SAIFULLAH DISTRICT	393,539	0.46	181	51	7	179	143	36	41	28
RURAL	329,214	0.42	138	41	3.49	145	116	29	33	30
URBAN	64,473	0.5	32	10	3.49	34	27	7	8	30
SHERANI DISTRICT	206,710	0.46	95	26	7	91	73	18	21	27
RURAL	206,710	0.42	87	26	3.49	91	73	18	21	30
ZHOB DISTRICT	372,278	0.46	171	48	7	168	134	34	38	28
RURAL	325,213	0.42	137	41	3.49	143	114	29	33	30

URBAN	47,251	0.5	24	7	3.49	25	20	5	6	30

Table 38. AJK MSW Data for Emissions Calculation

AJK Districts	Population (2025)	WGR	Daily waste generation (t/d)	Daily collected waste (t/d)	Fuel l/t	Daily fuel consumption (l/d)	Daily diesel (l/d)	Daily gasoline (l/d)	Daily diesel at TCP (l/d)	Daily diesel at LFS (l/d)	Daily energy consumption at LFS kWh/d	Collection efficiency (%)
Muzaffarabad	761268	0.255	194	136	3.5	474.2	379.4	94.8	27.2	108.7	13.6	70
Neelum	225564	0.382	86	60	3.5	210.5	168.4	42.1	12.1	48.3	6.0	70
Jhelum Valley	258267	0.354	91	64	3.5	223.4	178.7	44.7	12.8	51.2	6.4	70
Bagh	427291	0.271	116	81	3.5	282.9	226.3	56.6	16.2	64.8	8.1	70
Haveli	163580	0.369	60	42	3.5	147.5	118.0	29.5	8.5	33.8	4.2	70
Poonch	551439	0.20	108	75	3.5	262.7	210.2	52.5	15.1	60.2	7.5	70
Sudhnoti	335920	0.250	84	59	3.5	205.2	164.1	41.0	11.8	47.0	5.9	70
Kotli	884655	0.371	328	230	3.5	801.8	641.4	160.4	45.9	183.8	23.0	70
Mirpur	521905	0.193	101	71	3.5	246.1	196.9	49.2	14.1	56.4	7.1	70
Bhimber	481323	0.286	138	96	3.5	336.3	269.0	67.3	19.3	77.1	9.6	70
AJK Districts	4611212	0.2926	1306	914	3.5	3190.5	2552.4	638.1	182.8	731.3	91.4	70

Table 39. Islamabad MSW Data for Emissions Calculation

NAME OF ADMINISTRATIVE UNIT	Population (2025)	WGR	Daily waste generation (t/d)	Daily collected waste (t/d)	Fuel l/t	Daily fuel consumption (l/d)	Daily diesel (l/d)	Daily gasoline (l/d)	Daily diesel at TCP (l/d)	Daily diesel at LFS (l/d)	Collection efficiency (%)
ISLAMABAD	2,498,284	0.46	1,149	571	7	1994	1596	399	456	1429	50
RURAL	1,356,535	0.42	570	171	3.49	597	477	119	319	427	30
URBAN	1,144,410	0.5	572	401	3.49	1398	1118	280	137	1001	70

Table 40. Physical Waste Composition (%) at Punjab

SR.	Components	Lahore	Sheikhupura	Kasur	Nankana	Gujranwala	M. B.din	Sialkot	Narowal	Gujrat	Hafizabad
1	**Combustibles**	2.46	0.58	0.24	5.81	3.39	4.34	3.26	3.77	1.69	0.27
2	**Diaper**	9.81	6.28	16.71	15.94	11.01	13.56	11.16	12.2	15.98	19
3	**Elec.-Electronic W.**	1.79	0	0.02	0.42	0.05	0.16	0.17	0.16	0.49	0.02
4	**Glass**	8.87	0.14	0.41	0.87	1.53	2.33	1.84	1.93	0.48	0.43
5	**Hazardous W**	0.03	0.01	0.25	0	0	0.3	0	0	0.5	0.06
6	**Biodegradable W.**	49.42	70.5	63.15	47.47	50.34	50.92	52.3	50.42	54.04	65.43
7	**Metals**	0.06	0.02	0.01	0.03	0.31	0.14	0.12	0.08	0.31	0.05
8	**Non-Combustibles**	3.4	3.81	1.65	4.6	3.96	3.04	4.31	4.36	2.24	1.08
9	**Paper-Cardboard**	0.42	2.22	0.6	0.45	2.74	2.18	2.45	0.6	1.43	1.34
10	**Pet**	1.02	0	0.05	0.06	2.42	0.08	0.44	0.57	1.71	0.02
11	**Nylon**	0.42	0.28	0.29	0.94	0.7	0.23	0.84	0.85	1.42	0.18
12	**Plastics**	15.25	12.09	12.43	15.9	12.29	14.22	14.14	16.13	11.66	7.44
13	**Tetrapak**	2.11	0.05	0.06	0.59	2.91	2.12	1.15	1.49	0.7	0.03
14	**Textile**	4.93	4.03	4.15	6.94	8.26	6.01	7.98	7.44	7.35	4.64
Total		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Sr. No.	Components	Faisalabad	Jhang	Chiniot	T.T Singh	Sahiwal	Okara	Pakpattan	Wazirabad	Lodhran	Vehari
1	**Combustibles**	0.69	0.43	0.41	0.92	0.84	0.43	0.26	0.53	3.89	5.92
2	**Diaper**	13.12	16.64	14.08	13.3	12.02	19.32	9.83	17.36	14.1	13.55
3	**Elec.-Electronic W.**	0.05	0.03	0.07	0.03	0.03	0.03	0.05	0.04	0.19	0.02
4	**Glass**	0.47	0.67	0.31	0.64	0.42	0.73	1.84	0.4	2.25	0.77
5	**Hazardous W**	0.09	0.1	0.23	0.13	0.22	0.17	0.03	0.15	0.43	0.09
6	**Biodegradable W.**	61.7	65.91	68.02	69.02	61.16	61.71	73.52	62.51	51.83	51.05

7	**Metals**	0.14	0.05	0.02	0.05	0.04	0.06	0.25	0.07	0.12	0.01
8	**Non-Combustibles**	3.5	2.56	2.64	1.65	1.27	2.37	0.74	2.63	2.49	6.48
9	**Paper-Cardboard**	1.16	0.82	0.75	1.05	1.1	1.83	1.91	1.06	2.17	0.46
10	**Pet**	0.2	0.01	0.01	0.14	0.19	0.04	0.11	0.08	0.29	0.02
11	**Nylon**	0.42	0.27	0.29	0.26	0.13	0.24	0.2	0.1	0.21	0.15
12	**Plastics**	13.16	9.52	9.23	10.05	17.84	9.98	8.79	10.75	14.33	15.58
13	**Tetrapak**	0.32	0.04	0.02	0.05	0.1	0.07	0.04	0.16	1.63	0.06
14	**Textile**	4.97	2.93	3.92	2.7	4.64	3.02	2.43	4.14	6.13	5.83
Total		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Sr. No.	**Components**	**Rawalpindi**	**Attock**	**Chakwal**	**Jhelum**	**Talagang**	**Sargodha**	**Bhakkar**	**Khushab**	**Mianwali**	**Khanewal**
1	**Combustibles**	4.56	3.58	3.98	4.49	3.64	1.89	3.06	3.43	4.89	3.46
2	**Diaper**	11.41	14.71	13.45	13.35	11.21	14.82	11.65	11.69	11.23	14.51
3	**Elec.-Electronic W.**	0.2	0.3	0.04	0.38	0.56	0.02	0.02	0.04	0.02	0.31
4	**Glass**	1.56	3.21	2.6	1.23	0.61	0.44	1.53	1.27	2.23	2.52
5	**Hazardous W**	0.29	0	2.03	0	0.06	0.32	0	0	0.09	0
6	**Biodegradable W.**	52.83	49.88	48.11	50.13	54.12	56.35	56.59	51.99	55.59	49.11
7	**Metals**	0.38	0.5	0.34	0.19	0.06	0.02	0.12	0.09	0.07	0.62
8	**Non-Combustibles**	4.41	2.07	1.65	1.93	2.12	2.83	1.59	1.97	1.83	2.98
9	**Paper-Cardboard**	2.19	2.35	3.35	5.37	3.92	0.54	1.96	2.64	2.65	2.09
10	**Pet**	1.38	0.88	0.42	0.83	0.8	0.31	0	0.02	0.01	0.1
11	**Nylon**	0.75	0.31	0.13	0.43	0.19	0.44	0.7	0.81	0.78	0.4
12	**Plastics**	11.02	12.3	11.46	14.23	12.89	14.65	14.58	14.83	13.67	13.53
13	**Tetrapak**	2.13	2.53	1.67	0.93	0.99	0.5	0.85	0.42	0.4	1.47
14	**Textile**	7.22	6.95	10.49	6.34	8.5	6.19	6.14	5.38	6.6	8.75
Total		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Sr. No.	Components	Bahawalpur	Bahawalnagar	R.Y. Khan	DG Khan	Layyah	Taunsa	Kot Addu	Rajanpur	Muzaffargarh	Multan
1	**Combustibles**	2.87	3.89	5.3	6.71	4.1	5.49	6.01	8.59	6.77	5.27
2	**Diaper**	13.61	12.32	13.16	16.42	16.99	11.3	12.34	11.08	13.52	18.1
3	**Elec.-Electronic W.**	0.14	0.01	0.11	0.08	0.01	0.02	0	0.23	0.11	0.17
4	**Glass**	1.47	2.38	1.15	1.04	1.12	1.85	1.91	1.46	1.9	0.77
5	**Hazardous W**	0.06	0	0.05	0.01	0	0.02	0.22	0.02	0.06	0.31
6	**Biodegradable W.**	50.57	50.65	48.42	42.94	45.08	50.44	50.16	49.91	51.36	52.03
7	**Metals**	0.12	0	0.03	0.35	0	0.06	0.01	0.02	0.74	0.19
8	**Non-Combustibles**	5.47	5.34	5.88	8.12	6.28	4.38	4.37	3.21	6.24	3.28
9	**Paper-Cardboard**	0.66	0.43	0.66	0.83	1.08	0.67	1.58	1.89	1.3	1.23
10	**Pet**	0.25	0.01	0.49	0.11	0	0.01	0.93	0.32	0.2	0.39
11	**Nylon**	0.2	0.1	0.88	0.39	0.19	0.78	0.68	0.99	0.15	0.76
12	**Plastics**	16.38	16.68	17.27	14.06	16.54	15.68	14.65	12.88	10.67	7.37
13	**Tetrapak**	1.93	1.11	0.51	1.46	1.19	0.14	0.77	0.5	0.77	1.31
14	**Textile**	6.26	7.07	6.09	7.47	7.43	9.15	6.36	8.92	6.22	8.83
Total		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 41. Physical Waste Composition (%) at Other Proviances

Categories	Peshawar	Quetta	Islamabad	Karachi	Sukkur	Hyderabad	AJK	Mardan
Plastics	12.1	15	1	11.9	17.4	11.9	13	14.2
Organic	58.7	32.9	55.1	57.8	57.2	64	62	61.4
Paper and Cardboard	1.6	3.6	3.5	2.2	1.7	1.7	5	2.1
Textile	7	6.9	4.9	10.5	4.7	4.1	3	4.5
Glass	0.7	2	1.7	1.5	0.3	0.4	1	0.5
Metal	0	0.3	0.2	0	0	0	0	0
Diaper	8	0	13	12.2	11.8	11.5	8	10.6
Non-Combustible/Residue	9.6	34.4	1.4	1.6	3.4	3.8	4	4.7
Others	2.3	4.9	19.3	2.3	3.5	2.5	4	2
Total	100	100	100	100	100	100	100	100

Table 42. Phased MSW Treatment Approach based on Chemical Composition at National Level

Priority	Treatment Option	Why Suitable (Based on Composition)	Cost Level	Complexity	Expected Benefits
High	Source Separation and Informal Sector Integration	Reduces moisture/ inert entering system; improves recyclables recovery; increases CV of residual waste	Low	Low	Higher recycling, reduced landfill load, cost-effective system improvement
High	Decentralized Composting (Windrow method)	High volatile matter reflects strong organic fraction; moisture suits composting; cheap & scalable	Low	Low	Compost for agriculture, reduced methane emissions, low-tech
High	Small and Medium Anaerobic Digesters (for food/market waste)	High moisture and organics are good for biogas production	Low–Med	Medium	Biogas energy, nutrient-rich digestate
Medium	Low-Tech Mechanical Sorting (MRF)	High ash/ inert require removal; raises calorific value of remaining waste	Low–Med	Medium	Recyclables revenue; cleaner feedstock for RDF/energy
Medium	Bio-drying to Produce RDF	Reduces 50% moisture; increases NCV; suitable since CV ~11.8 MJ/kg	Medium	Medium	RDF sales; lower landfill volume; supports local industries
Medium	Co-processing in Cement Kilns (RDF)	Cement kilns tolerate high ash (21%); good outlet for RDF	Low (to municipality)	Medium	Safe destruction of waste, energy recovery, minimal residues
Medium	Mechanical-Biological Treatment (MBT)	Combines sorting + bio-drying + composting for maximum stabilization	Medium	Medium	Stabilized organics, recyclables recovery, energy fraction recovery
Medium	Controlled Sanitary Landfill with landfill gas capture	Needed for remaining inert/ash fraction; high ash % makes this essential	Medium	Medium	Reduced leachate & pollution; partial methane capture
Low	Mass Burn Incineration (WtE)	CV moderate but moisture/ash high that requires pre-treatment to be viable	High	High	Electricity generation but expensive and high O&M costs
Low	Gasification/ Pyrolysis	Feedstock variability and high ash makes unreliable	High	High	Only feasible with high-quality RDF; not suitable initially

Table 43. Faisalabad MSW Chemcial Analysis Results

FAISLABAD					
Sr. No.	**Parameters**	**Methods**	**AR (As received)**	**Dry**	**AD (Air dry)**
1	**Moisture, Total %**	Based on ASTM D3302	57.53	0.00	0.00
2	**Moisture, Laboratory Sample %**	Based on ASTM D3173	0.00	0.00	5.65
3	**Ash %**	Based on ASTM D3174	12.78	27.47	26.15
4	**Volatile Matter %**	Based on ASTM D3175	25.33	61.69	58.02
5	**Fixed Carbon by Calculation %**	Based on ASTM D3172	4.37	10.85	10.19
6	**Sulfur %**	Based on ASTM D4239 Method A	0.19	0.36	0.35
7	**Gross Calorific Value kcal/kg**	Based on ASTM D5865	1754.75	4110.00	3879.00
8	**Net CV @ Constant Pressure kcal/kg**	Based on ASTM D5865	1306.75	3839.25	3591.00
9	**Oxygen (by difference) %**	Based on ASTM D31761	10.31	28.23	31.33
10	**Carbon %**	Based on ASTM D5373	16.63	37.59	35.58
11	**Hydrogen %**	Based on ASTM D5373	2.18	5.24	5.57
12	**Nitrogen %**	Based on ASTM D5373	0.41	1.11	1.04

Table 44. Gujranwala MSW Chemcial Analysis Results

GUJRAWALA					
Sr. No.	**Tests**	**Methods**	**AR**	**Dry**	**AD**
1	**Moisture, Total %**	Based on ASTM D3302	65.315	0	0
2	**Moisture, Laboratory Sample %**	Based on ASTM D3173	0	0	9.02
3	**Ash %**	Based on ASTM D3174	13.27	38.285	35.12
4	**Volatile Matter %**	Based on ASTM D3175	20.62	59.0825	53.8
5	**Fixed Carbon by Calculation %**	Based on ASTM D3172	3.045	8.96	8.00
6	**Sulfur %**	Based on ASTM D4239 Method A	0.07	0.205	0.18
7	**Gross Calorific Value kcal/kg**	Based on ASTM D5865	1077.25	3101	2807
8	**Net CV @ Constant Pressure kcal/kg**	Based on ASTM D5865	588	2678.5	2423.5
9	**Oxygen (by difference) %**	Based on ASTM D31761	8.2825	23.9825	29.65
10	**Carbon %**	Based on ASTM D5373	11.015	31.69	28.71
11	**Hydrogen %**	Based on ASTM D5373	1.63	4.67	5.25
12	**Nitrogen %**	Based on ASTM D5373	0.4115	1.17	1.06

Table 45. Lahore MSW Chemcial Analysis Results

LAHORE					
SN	**Tests**	**Methods**	**AR**	**Dry**	**AD**
1	**Moisture, Total %**	Based on ASTM D3302	78.15	-	-
2	**Moisture, Laboratory Sample %**	Based on ASTM D3173	-	-	4.80
3	**Ash %**	Based on ASTM D3174	4.69	21.28	20.26
4	**Volatile Matter %**	Based on ASTM D3175	15.05	69.05	65.74
5	**Fixed Carbon by Calculation %**	Based on ASTM D3172	2.12	9.68	9.21
6	**Sulfur %**	Based on ASTM D4239 Method A	0.05	0.20	0.19
7	**Gross Calorific Value kcal/kg**	Based on ASTM D5865	1074	5122	4307
8	**Net CV @ Constant Pressure kcal/kg**	Based on ASTM D5865	459	4206	3976
9	**Oxygen (by difference) %**	Based on ASTM D31761	5.23	23.96	27.07
10	**Carbon %**	Based on ASTM D5373	10.31	47.31	45.04
11	**Hydrogen %**	Based on ASTM D5373	1.35	6.17	6.42
12	**Nitrogen %**	Based on ASTM D5373	0.23	1.083	1.032

Table 46. Sahiwal MSW Chemcial Analysis Results

SAHIWAL				
SN	**Parameter**	**AR**	**Dry**	**AD**
1	**Moisture, Total %**	49.34	-	-
2	**Moisture, Laboratory Sample %**	-	-	2.88
3	**Ash %**	21.68	42.84	41.61
4	**Volatile Matter %**	24.26	47.83	46.44
5	**Fixed Carbon by Calculation %**	4.73	9.33	9.07
6	**Sulfur %**	0.22	0.43	0.42
7	**Gross Calorific Value kcal/kg**	1105	2183	2120
8	**Net CV @ Constant Pressure kcal/kg**	716	1983	1909
9	**Oxygen (by difference) %**	12.20	24.03	25.89
10	**Carbon %**	14.14	27.91	27.11
11	**Hydrogen %**	1.95	3.85	4.06
12	**Nitrogen %**	0.48	0.95	0.92

Table 47. Multan MSW Chemcial Analysis Results

MULTAN				
Sr.No.	**Parameter**	**AR**	**Dry**	**AD**
1	**Moisture, Total %**	58.59	0	0
2	**Moisture, Laboratory Sample %**	0	0	3.53
3	**Ash %**	15.57	37.34	36.22
4	**Volatile Matter %**	25.97	63.13	60.56
5	**Fixed Carbon by Calculation %**	3.09	7.30	7.18
6	**Sulfur %**	0.17	0.42	0.40
7	**Gross Calorific Value kcal/kg**	1310	3180	3054
8	**Net CV @ Constant Pressure kcal/kg**	1101	3585	3359
9	**Oxygen (by difference) %**	8.95	21.66	24.00
10	**Carbon %**	14.35	34.82	33.45
11	**Hydrogen %**	2.01	4.88	5.08
12	**Nitrogen %**	0.371	0.893	0.863

Table 48. Rawalpindi MSW Chemcial Analysis Results

RAWALPINDI					
Sr. No.	**Parameter**	**Methods**	**AR**	**DRY**	**AD**
1	**Moisture, Total %**	Based on ASTM D3302	23.5	-	-
2	**Moisture, Laboratory Sample %**	Based on ASTM D3173	-	-	1.89
3	**Ash %**	Based on ASTM D3174	13.8	19.2	18.8
4	**Volatile Matter %**	Based on ASTM D3175	49.79	65	63.81
5	**Fixed Carbon by Calculation %**	Based on ASTM D3172	12.81	15.76	15.49
6	**Sulfur %**	Based on ASTM D4239 Method A	0.325	0.41	0.4
7	**Gross Calorific Value kcal/kg**	Based on ASTM D5865	4537	5763	5658
8	**Net CV @ Constant Pressure kcal/kg**	Based on ASTM D5865	4152	5444	5334
9	**Oxygen (by difference) %**	Based on ASTM D31761	12.15	17.16	18.48

10	**Carbon %**	Based on ASTM D5373	44.73	56.3	55.3
11	**Hydrogen %**	Based on ASTM D5373	4.84	6.23	6.33
12	**Nitrogen %**	Based on ASTM D5373	0.55	0.69	0.67

Table 49. Rawalpindi MSW Chemcial Analysis Results

QUETTA	
Parameter	**Value**
Moisture	26.67
Calorific Value BTU	5399.63
Organic Matter %	22.06
Volatile Matter %	71.43
Ash Content %	15.4
Fixed Carbon	13.26

Table 50: Greenhouse Gas Emission Inventory of Punjab.

Sr. No.	District	Emissions per tonne of generated waste		Emissions per tonne of collected waste		Emissions form yearly generated waste		Emissions from yearly collected waste	
		BC Emission (Tonnes)	Climate Impact from GHG Emissions (Tonnes of CO_2 Eq)	BC Emission (Tonnes)	Climate Impact from GHG Emissions (Tonnes of CO_2 Eq)	BC Emission (Tonnes)	Climate Impact from GHG Emissions (Tonnes of CO_2 Eq)	BC Emission (Tonnes)	Climate Impact from GHG Emissions (Tonnes of CO_2 Eq)
1	**Chiniot**	0.016	923.5	0.017	1060.0	3.484	198872.3	2.730	166748.4
2	**Faisalabad**	0.016	935.3	0.017	1041.9	17.630	1042533.1	14.470	908157.7
3	**Gujrat**	0.017	934.2	0.018	1059.1	7.923	444665.4	6.338	374984.0
4	**Hafizabad**	0.016	1150.2	0.017	1327.2	3.045	215361.3	2.457	188439.5
5	**Jhang**	0.016	930.9	0.017	1095.6	6.631	386687.2	4.980	315921.1
6	**Kasur**	0.016	1082.2	0.016	1234.0	8.901	619357.3	7.255	549954.6
7	**Okara**	0.017	1040.8	0.018	1188.2	8.303	516649.1	6.757	448436.4
8	**Pakpattan**	0.016	894.6	0.017	980.3	4.787	260579.5	4.037	228987.3
9	**Sahiwal**	0.016	882.9	0.017	975.3	6.344	348986.7	5.291	306514.6
10	**Sargodha**	0.017	746.1	0.018	831.0	10.589	468137.3	8.217	369722.9
11	**Sheikhupura**	0.016	991.5	0.017	1113.8	9.167	575402.2	7.601	512223.8
12	**Toba Tek Singh**	0.016	891.0	0.017	1002.2	5.479	301473.0	4.388	254954.4
13	**Wazirabad**	0.017	1125.0	0.018	1282.8	2.386	159739.1	1.983	142339.2
14	**DG Khan**	0.038	942.0	0.040	1033.7	12.466	308414.2	10.295	269403.3
15	**Layyah**	0.018	722.5	0.020	783.9	4.980	200170.5	4.050	161079.8
16	**Rajanpur**	0.018	757.2	0.020	787.0	6.130	252869.6	5.314	213440.3
17	**Taunsa**	0.015	637.0	0.019	780.8	3.110	131821.6	1.373	57284.1
18	**Kot Addu**	0.018	701.1	0.019	736.3	3.469	135636.0	2.962	113684.8
19	**Muzaffargarh**	0.017	610.2	0.020	635.9	8.106	293347.9	5.568	181502.0
20	**Bahawalpur**	0.038	866.9	0.041	1023.8	16.027	366106.6	11.602	292973.0
21	**Bahawalnagar**	0.037	918.6	0.039	1110.8	18.269	456351.8	13.038	372999.3

22	**Rahim Yar Khan**	0.036	875.6	0.038	1012.6	27.497	659929.4	20.546	546638.2
23	**Multan**	0.035	806.9	0.038	988.5	20.943	477397.4	11.334	292620.5
24	**Khanewal**	0.035	1136.2	0.036	1249.6	16.165	517984.9	13.306	459743.1
25	**Lodhran**	0.035	1083.0	0.036	1229.6	8.862	272345.7	6.738	228885.7
26	**Vehari**	0.036	727.3	0.037	767.3	16.910	341116.0	13.980	290696.5
27	**Lahore**	0.046	761.0	0.049	820.0	96.060	1573355.1	85.847	1437523.2
28	**Nankana**	0.017	833.8	0.018	918.6	3.687	184117.6	2.999	154226.6
29	**Rawalpindi**	0.034	1012.4	0.035	1124.8	32.928	970770.8	26.569	858474.5
30	**Murree**	0.018	1262.4	0.020	1449.1	1.002	70500.7	0.812	59768.1
31	**Chakwal**	0.015	1072.9	0.016	1158.0	2.473	171524.9	2.150	156392.4
32	**Attock**	0.018	1079.6	0.019	1227.6	5.335	321935.3	4.433	280950.8
33	**Jhelum**	0.017	1097.3	0.019	1294.5	3.489	220721.1	2.734	185213.8
34	**Talagang**	0.018	1109.0	0.019	1163.7	1.449	87431.9	1.349	82829.8
35	**Gujranwala**	0.036	1048.4	0.037	1159.6	27.670	803244.6	22.949	719955.8
36	**Mandi Bahauddin**	0.018	1041.1	0.020	1189.0	4.354	250416.6	3.590	216128.7
37	**Narowal**	0.017	822.8	0.020	1019.9	4.443	211432.5	3.139	159703.5
38	**Sialkot**	0.028	1023.3	0.027	1128.6	17.795	644691.9	14.070	581634.0
39	**Bhakkar**	0.019	914.3	0.022	1031.7	5.109	239616.8	4.260	202971.1
40	**Khushab**	0.025	937.2	0.031	1117.5	5.097	192925.9	4.220	154584.7
41	**Mianwali**	0.020	978.9	0.022	1119.9	4.664	232961.9	3.853	196623.3
TOTAL		**0.023**	**934.3**	**0.024**	**1055.0**	**473.160**	**16127582.6**	**379.581**	**13695314.7**

Table 51: Greenhouse Gas Inventory of Sindh

District	Emissions per tonne of generated waste		Emissions per tonne of collected waste		Emissions from yearly generated waste		Emissions from yearly collected waste	
	BC	GHG	BC	GHG	BC	GHG	BC	GHG
	kg/ton	kg of CO_2-eq/ tonne	kg/ton	kg of CO_2-eq/ ton	Tons	Tons of CO_2-eq	Tons	Tons of CO2-eq
Badin	0.021	535.120	0.023	561.628	6.317	162,895.947	2.616	64,368.237
Dadu	0.021	535.587	0.023	561.610	5.774	148,767.316	2.457	60,471.330
Ghotki	0.021	534.977	0.023	561.604	5.731	147,816.937	2.357	58,010.930
Hyderabad	0.022	546.417	0.023	561.627	9.270	234,145.312	6.281	154,565.238
Jacobabad	0.021	536.371	0.023	561.651	3.995	102,782.155	1.775	43,665.529
Jamshoro	0.021	538.531	0.023	561.616	3.912	100,247.585	1.941	47,762.631
Kambar	0.021	535.839	0.023	561.629	5.058	130,257.023	2.183	53,708.571
Karachi Central	0.022	550.997	0.023	561.630	20.027	501,778.913	15.586	383,545.661
Karachi East	0.022	551.006	0.023	561.626	20.951	524,916.112	16.310	401,377.521
Karachi South	0.022	549.766	0.022	559.975	12.088	307,618.782	3.362	235,049.334
Karachi West	0.022	550.283	0.023	561.626	13.563	340,245.340	10.346	254,602.022
Kashmore	0.021	535.028	0.023	561.632	4.066	104,868.189	1.675	41,204.131
Kemari	0.022	550.999	0.023	561.638	10.620	266,074.512	8.264	203,357.835
Khairpur	0.021	536.549	0.023	561.616	8.650	222,474.495	3.881	95,525.330
Korangi	0.022	550.997	0.023	561.631	16.078	402,830.803	12.512	307,903.144
Larkana	0.010	250.678	0.023	561.628	6.280	161,050.161	3.049	75,027.891
Malir	0.022	546.269	0.023	561.632	10.244	258,805.940	6.906	169,941.525
Matiari	0.021	534.222	0.023	561.557	2.777	71,756.739	1.091	26,850.840
Mirpur Khas	0.021	536.132	0.023	561.603	5.618	144,613.618	2.465	60,675.588
Naushera Feroze	0.021	536.258	0.023	561.621	5.941	152,868.402	2.624	64,572.416
Sajawal	0.021	532.921	0.023	561.627	2.636	68,275.183	0.950	23,369.285
Sanghar	0.021	535.816	0.023	561.626	7.693	198,115.356	3.315	81,587.391
Shaheed Benazir Abad	0.021	536.630	0.023	561.638	6.269	161,200.866	2.824	69,494.306
Shikarpur	0.021	535.175	0.023	561.592	4.568	117,789.288	1.899	46,735.651
Sukkur	0.021	538.831	0.023	561.626	5.729	146,718.350	2.882	70,927.804

Tando Allahyar	0.021	536.282	0.023	561.666	3.074	79,080.115	1.358	33,416.310
Tando Muhammad Khan	0.021	534.126	0.023	561.558	2.346	60,631.312	0.916	22,546.562
Tharparkar	0.021	532.685	0.023	561.604	5.568	144,267.080	1.974	48,581.516
Thatta	0.021	533.655	0.023	561.551	3.494	90,379.895	1.324	32,589.604
Umer Kot	0.021	535.122	0.023	561.661	3.765	97,073.875	1.558	38,336.202
Total	**0.021**	**529.776**	**0.023**	**561.56**	**222.102**	**5,650,345**	**126.681**	**3,269,770**

Table 52: Greenhouse Gas Inventory of Khyber-Pakhtunkhwa

District	Waste Generation ton/day		Waste Collection ton/day		Waste Generation ton/Year		Waste Collection ton/Year	
	BC	GHG	BC	GHG	BC	GHG	BC	GHG
	Kg/ ton	CO_2-eq./ ton	Kg/ ton	CO_2-eq./ ton	Kg/ ton	CO_2-eq./ ton	Tons	CO_2-eq./ ton
Abbottabad District	0.0244	215.159	0.0685	603.311	4.973	43821.52	4.9733	43821.523
Bajaur District	0.0317	593.087	0.0683	602.797	6.064	113433.91	3.2666	28822.717
Bannu District	0.0323	593.239	0.0683	602.805	6.395	117576.92	3.5409	31243.362
Batagram District	0.0321	594.481	0.0701	608.369	2.628	48604.73	1.4322	12435.059
Buner District	0.0317	593.085	0.0683	602.785	4.721	88322.17	2.5433	22441.694
Charsadda District	0.0349	593.402	0.0677	600.954	9.407	159844.61	5.8343	51766.192
Dera Ismail Khan District	0.0361	594.200	0.0683	602.634	9.527	156806.52	6.1324	54110.490
Hangu District	0.0343	593.736	0.0683	602.697	2.563	44426.31	1.5454	13639.027
Haripur District	0.0337	593.622	0.0683	602.791	5.872	103352.56	3.4660	30582.625
Karak District	0.0328	593.389	0.0683	602.824	3.953	71473.71	2.2444	19802.753
Khyber District	0.0330	593.424	0.0683	602.804	5.583	100502.33	3.1918	28162.991
Kohat District	0.0366	594.383	0.0683	602.813	6.567	106739.22	4.2890	37844.613
Upper Kohistan District	0.0316	593.098	0.0683	602.912	2.090	39183.05	1.1225	9902.836
Kurram District	0.0326	593.328	0.0683	602.812	3.903	71033.28	2.1944	19362.322
Lakki Marwat District	0.0415	595.682	0.0683	602.808	6.357	91318.01	4.7129	41584.709
Lower Chitral District	0.0343	592.896	0.0673	599.671	1.616	27916.51	0.9829	8755.201
Lower Dir District	0.0321	593.119	0.0682	602.506	7.799	144181.38	4.2827	37825.323
Lower Kohistan District	0.0318	593.516	0.0689	604.510	1.813	33794.80	0.9802	8605.206
Malakand District	0.0331	593.463	0.0683	602.784	4.027	72132.45	2.3188	20461.493
Mansehra	0.0330	593.456	0.0683	602.870	8.750	157259.77	5.0130	44229.553
Mardan District	0.0352	594.023	0.0683	602.848	14.238	240451.69	8.8784	78334.057
Mohmand District	0.0317	593.078	0.0683	602.816	2.599	48706.52	1.3965	12321.549
North Waziristan	0.0318	593.102	0.0683	602.764	3.365	62779.82	1.8201	16060.659
Nowshera District	0.0359	594.195	0.0683	602.808	9.177	152033.62	5.8600	51705.841
Orakzai District	0.0317	593.080	0.0683	602.766	1.990	37233.55	1.0720	9460.407
Peshawar	0.0424	595.925	0.0683	602.815	29.247	411316.47	22.0939	194944.336

Shangla District	0.0316	593.084	0.0683	602.854	4.180	78364.17	2.2445	19803.752
Sawabi	0.0357	594.154	0.0683	602.811	10.010	166553.35	6.3588	56106.675
Tank	0.0333	593.531	0.0683	602.834	2.275	40511.44	1.3217	11661.823
Sawat	0.0382	594.806	0.0683	602.823	15.164	236426.62	10.3740	91532.641
Torgar	0.0316	593.095	0.0683	602.991	0.933	17534.87	0.4989	4401.833
Uper Chitral	0.0319	593.108	0.0683	602.717	0.919	17102.28	0.4986	4399.835
Upper Dir District	0.0324	593.275	0.0683	602.831	5.153	94413.74	2.8679	25303.835
South Waziristan District	0.0317	593.080	0.0683	602.734	4.343	81177.87	2.3435	20679.789
Total	**0.0335**	**582.509**	**0.0683**	**602.878**	**208.202**	**3476329.7**	**131.6959**	**1162116.7**

Table 53: Greenhouse Gas Inventory of Baluchistan.

District	Waste Generation ton/day		Waste Collection tons/day		Waste Generation ton/Year		Waste Collection ton/Year	
	BC	GHG	BC	GHG	BC	GHG	BC	GHG
	Kg/ ton	CO_2-eq./ ton	Kg/ ton	CO_2-eq./ ton	Kg/ ton	CO_2-eq./ ton	Tons	CO_2-eq./ ton
Awaran	0.03615	321.282	0.0684	333.027	1.240	11023.185	0.799	3889.75
Kalat District	0.03338	320.302	0.0686	333.203	1.681	16133.631	0.977	4743.15
Khuzdar District	0.05392	337.774	0.0717	349.423	2.716	17013.678	2.381	11606.08
Lasbela District	0.04156	322.361	0.0679	330.872	5.021	38945.984	3.740	18236.02
Mastung District	0.03307	319.288	0.0675	329.598	1.835	17714.073	1.059	5173.04
Surab District	0.03343	320.339	0.0686	333.263	1.721	16486.231	1.002	4865.64
Barkhan District	0.03319	320.236	0.0686	333.206	1.260	12156.143	0.726	3526.99
Duki District	0.03319	320.236	0.0686	333.206	1.260	12156.143	0.726	3526.99
Loralai District	0.03874	320.552	0.0676	328.550	1.838	15210.198	1.283	6235.88
Musakhel District	0.03320	320.228	0.0686	333.165	1.042	10051.961	0.601	2918.53
Gwadar District	0.03443	320.677	0.0686	333.167	1.860	17322.963	1.127	5472.26
Kech District	0.03968	321.877	0.0680	331.208	7.444	60387.255	5.309	25870.65
Panjgur District	0.03380	320.519	0.0687	333.434	3.393	32172.070	2.005	9736.27
Jaffarabad District	0.03440	320.687	0.0681	333.050	3.603	33593.596	2.187	10697.58
Jhal Magsi	0.03367	320.431	0.0686	333.286	1.278	12163.576	0.751	3649.48
Kachhi District	0.03339	320.365	0.0686	333.425	2.803	26894.631	1.629	7910.50
Nasirabad District	0.03341	320.362	0.0686	333.383	3.317	31805.511	1.929	9369.72
Sohbatpur District	0.03335	320.283	0.0686	333.171	1.424	13677.692	0.826	4013.04
Chamn	0.03358	320.438	0.0687	333.442	2.696	25731.196	1.579	7667.50
Killa Abdullah District	0.03314	320.289	0.0687	333.489	2.093	20224.645	1.203	5842.72
Pishin District	0.03951	323.051	0.0690	334.605	5.783	47283.420	4.081	19785.19
Quetta District	0.04866	324.091	0.0675	329.838	22.182	147748.376	18.687	91256.19
Chagai District	0.03301	320.252	0.0687	333.530	1.579	15312.845	0.902	4382.59
Kharan District	0.03388	320.483	0.0686	333.191	1.731	16376.690	1.027	4986.21
Nushki District	0.03360	320.385	0.0686	333.206	1.239	11810.976	0.726	3526.99
Washuk District	0.03333	320.333	0.0686	333.386	2.032	19525.880	1.178	5719.24

Dera Bugti District	0.03367	320.483	0.0687	333.480	2.089	19885.993	1.228	5964.29
Harnai District	0.03407	320.519	0.0686	333.069	0.796	7487.322	0.476	2309.83
Kohlu District	0.03016	320.191	0.0501	243.064	1.409	14959.319	0.640	3105.15
Sibi District	0.03369	321.622	0.0687	337.425	1.365	13030.500	0.803	3941.13
Ziarat District	0.03820	322.161	0.0687	333.465	1.283	10818.173	0.877	4260.02
Killa Saifullah District	0.03335	320.343	0.0686	333.402	2.203	21163.484	1.278	6206.29
Sherani District	0.03295	320.209	0.0687	333.449	1.143	11103.247	0.652	3164.43
Zhob District	0.03329	320.316	0.0686	333.376	2.078	19992.548	1.203	5840.74
Total	**0.03541**	**321.264**	**0.0680**	**330.796**	**96.436**	**817363.13**	**65.595**	**319400.07**

Table 54: Greenhouse Gas Inventory of Azad Jammu And Kashmir.

Districts	Emissions per tonne of generated waste		Emissions per tonne of collected waste		Emissions from yearly generated waste		Emissions from yearly collected waste	
	BC	GHG	BC	GHG	BC	GHG	BC	GHG
	Kg/ ton	CO_2-eq./ ton	Kg/ ton	CO_2-eq./ ton	Kg/ ton	CO_2-eq./ ton	Tons	CO_2-eq./ ton
Muzaffarabad	0.015	578.155	0.015	593.733	1.03	40939.172	0.755	29472.882
Neelum	0.015	578.008	0.015	593.773	0.457	18143.679	0.333	13003.618
Jhelum Valley	0.015	578.301	0.015	593.772	0.484	19208.268	0.356	13870.512
Bagh	0.015	578.027	0.015	593.755	0.616	24473.671	0.45	17554.358
Haveli	0.015	578.131	0.015	593.774	0.319	12661.063	0.233	9102.559
Poonch	0.015	577.851	0.015	593.789	0.573	22778.906	0.417	16254.982
Sudhnoti	0.015	578.206	0.015	593.704	0.446	17727.785	0.328	12785.418
Kotli	0.015	578.160	0.015	593.726	1.742	69217.360	1.277	49843.284
Mirpur	0.015	578.191	0.015	593.640	0.536	21315.022	0.394	15384.183
Bhimber	0.015	577.903	0.015	593.773	0.733	29108.977	0.533	20805.802
Average/ Total	0.015	578.0933	0.015	593.7439	**6.936**	**275573.903**	**5.076**	**198077.598**

Scenarios of Karachi for Economic Modelling

Table 55: Scenario-1 Karachi Waste Diversion

Scenario -1					
Waste Composition	**Collected Waste (t/d)**	**Diverted Waste (t/d)**	**Compost (t/d)**	**Recovery of Recyclables (t/d)**	**LF Methane Capturing (Organic t/d)**
Combustibles	152	30	30		
Diaper	1161	232			
Elec.-Electro.	0	0			
Glass	148	30		30	
Hazardous	0	0			
Biodegradable	5517	1103	1103		
Metals	0	0		0	
Non-Combust.	220	44			
Paper-Card.	210	42		42	
PET	0	0		0	
Nylon	0	0		0	
Plastics	1133	227		227	
Tetrapak	0	0		0	
Textile	1003	201		201	
Total	**9544**	**1909**	**1134**	**499**	**4574**

Table 56: Scenario-2 Karachi Waste Diversion

Scenario-2						
Waste Composition	**CW**	**DW**	**Compost**	**Anaerobic Digestion**	**Recovery of Recyclables**	**LF Methane Capturing (Organic)**
Combustibles	152	61	30	30		
Diaper	1161	465				
Elec.-Electro.	0	0				
Glass	148	59			59	
Hazardous	0	0				
Biodegradable	5517	2207	1103	1103		
Metals	0	0			0	
Non-Combust.	220	88				
Paper-Card.	210	84			84	
PET	0	0			0	
Nylon	0	0			0	
Plastics	1133	453			453	
Tetrapak	0	0			0	
Textile	1003	401			401	
Total	**9544**	**3818**	**1134**	**1134**	**997**	**3630**

Table 57: Scenario-3 Karachi Waste Diversion

Scenario-3							
Waste Composition	**CW**	**DW**	**Compost**	**Anaerobic Digestion**	**Recovery of Recyclables**	**RDF**	**LF Methane Capturing (Organic)**
Combustibles	152	91	46	46			
Diaper	1161	697					
Elec.-Electro.	0	0					
Glass	148	89			89		
Hazardous	0	0					
Biodegradable	5517	3310	1655	1655			
Metals	0	0			0		
Non-Combust.	220	132					
Paper-Card.	210	126			63	63	
PET	0	0			0	0	
Nylon	0	0			0	0	
Plastics	1133	680			340	340	
Tetrapak	0	0					
Textile	1003	602			301	301	
Total	**9544**	**5726**	**1701**	**1701**	**792**	**704**	**2686**

Table 58: Scenario-4 Karachi Waste Diversion

Scenario-4									
Waste Composition	**CW**	**TW**	**Compost**	**Anaerobic Digestion**	**MBT**	**Recovery of Recyclables**	**RDF**	**LF Methane Capturing (Organic)**	**Incineration**
Combustibles	152	122	43	43	36				
Diaper	1161	929							
Elec.-Electro.	0	0							
Glass	148	118				118			
Hazardous	0	0							
Biodegradable	5517	4414	1545	1545	1324				
Metals	0	0				0			
Non-Combust.	220	176							
Paper-Card.	210	168				84	84		
PET	0	0				0	0		
Nylon	0	0				0	0		
Plastics	1133	906				453	453		
Tetrapak	0	0							
Textile	1003	802				401	401		
Total	**9544**	**7635**	**1587**	**1587**	**1361**	**1056**	**938**	**1394**	**603**

Scenarios of Lahore for Economic Modelling

Table 59: Scenario-1 Lahore Waste Diversion

Scenario - 1					
Waste Composition	**CW**	**DW**	**Compost**	**Recovery of Recyclables**	**LF Methane Capturing (Organic)**
Combustibles	98	20	20		
Diaper	390	78			
Elec.-Electro.	71	14			
Glass	352	70		70	
Hazardous	1	0			
Biodegradable	1963	393	393		
Metals	2	0		0	
Non-Combust.	135	27			
Paper-Card.	17	3		3	
PET	41	8		8	
Nylon	17	3		3	
Plastics	606	121		121	
Tetrapak	84	17		17	
Textile	196	39		39	
Total	**3972**	**794**	**412**	**263**	**1629**

Table 60: Scenario-2 Lahore Waste Diversion

Scenario - 2						
Waste Composition	**CW**	**DW**	**Compost**	**Anaerobic Digestion**	**Recovery of Recyclables**	**LF Methane Capturing (Organic)**
Combustibles	98	39	20	20		
Diaper	390	156				
Elec.-Electro.	71	28				
Glass	352	141			141	
Hazardous	1	0				
Biodegradable	1963	785	393	393		
Metals	2	1			1	
Non-Combust.	135	54				
Paper-Card.	17	7			7	
PET	41	16			16	
Nylon	17	7			7	
Plastics	606	242			242	
Tetrapak	84	34			34	
Textile	196	78			78	
Total	**3972**	**1589**	**412**	**412**	**526**	**1296**

Table 61: Scenario-3 Lahore Waste Diversion

Scenario - 3

Waste Composition	CW	DW	Compost	Anaerobic Digestion	Recovery of Recyclables	RDF	LF Methane Capturing (Organic)
Combustibles	98	59	29	29			
Diaper	390	234					
Elec.-Electro.	71	43					
Glass	352	211			211		
Hazardous	1	1					
Biodegradable	1963	1178	589	589			
Metals	2	1			1		
Non-Combust.	135	81					
Paper-Card.	17	10			5	5	
PET	41	24			12	12	
Nylon	17	10			5	5	
Plastics	606	363			182	182	
Tetrapak	84	50			25	25	
Textile	196	117			59	59	
Total	**3972**	**2383**	**618**	**618**	**501**	**288**	**962**

Table 62: Scenario-4 Lahore Waste Diversion

Scenario - 4

Waste Composition	CW	DW	Compost	AD	MBT	Recovery of Recyclables	RDF	LF Methane Capturing (Organic)	Incineration
Combustibles	98	78	27	27	23				
Diaper	390	312							
Elec.-Electro.	71	57							
Glass	352	282				282			
Hazardous	1	1							
Biodegradable	1963	1570	550	550	471				
Metals	2	2				2			
Non-Combust.	135	108							
Paper-Card.	17	13				7	7		
PET	41	32				16	16		
Nylon	17	13				7	7		
Plastics	606	485				242	242		
Tetrapak	84	67				34	34		
Textile	196	157				78	78		
Total	**3972**	3177	**577**	**577**	**495**	**667**	**384**	**503**	**254**

Scenarios of Peshawar for Economic Modelling

Table 63: Scenario-1 Peshawar Waste Diversion

Scenario - 1					
Waste Composition	**CW**	**DW**	**Compost**	**Recovery of Recyclables**	**LF Methane Capturing (Organic)**
Combustibles	85	17	17		
Diaper	71	14			
Elec.-Electro.	0	0			
Glass	7	1		1	
Hazardous	0	0			
Biodegradable	520	104	104		
Metals	0	0		0	
Non-Combust.	20	4			
Paper-Card.	14	3		3	
PET	0	0		0	
Nylon	0	0		0	
Plastics	108	22		22	
Tetrapak	0	0			
Textile	62	12		12	
Total	**886**	**177**	**121**	**38**	**427**

Table 64: Scenario-2 Peshawar Waste Diversion

Scenario - 2						
Waste Composition	**CW**	**DW**	**Compost**	**Anaerobic Digestion**	**Recovery of Recyclables**	**LF Methane Capturing (Organic)**
Combustibles	85	34	17	17		
Diaper	71	28				
Elec.-Electro.	0	0				
Glass	7	3			3	
Hazardous	0	0				
Biodegradable	520	208	104	104		
Metals	0	0			0	
Non-Combust.	20	8				
Paper-Card.	14	6			6	
PET	0	0			0	
Nylon	0	0			0	
Plastics	108	43			43	
Tetrapak	0	0				
Textile	62	25			25	
Total	**886**	**354**	**121**	**121**	**76**	**333**

Table 65: Scenario-3 Peshawar Waste Diversion

Scenario -3							
Waste Composition	**CW**	**DW**	**Compost**	**Anaerobic Digestion**	**Recovery of Recyclables**	**RDF**	**LF Methane Capturing (Organic)**
Combustibles	85	51	25	25			
Diaper	71	42					
Elec.-Electro.	0	0					
Glass	7	4			4		
Hazardous	0	0					
Biodegradable	520	312	156	156			
Metals	0	0			0		
Non-Combust.	20	12					
Paper-Card.	14	8			4	4	
PET	0	0			0	0	
Nylon	0	0			0	0	
Plastics	108	65			32	32	
Tetrapak	0	0					
Textile	62	37			19	19	
Total	**886**	**532**	**181**	**181**	**59**	**55**	**240**

Table 66: Scenario-4 Peshawar Waste Diversion

Scenario - 4									
Waste Composition	**CW**	**DW**	**Compost**	**AD**	**MBT**	**Recovery of Recyclables**	**RDF**	**LF Methane Capturing (Organic)**	**Incineration**
Combustibles	85	68	24	24	20				
Diaper	71	57							
Elec.-Electro.	0	0							
Glass	7	5				5			
Hazardous	0	0							
Biodegradable	520	416	146	146	125				
Metals	0	0				0			
Non-Combust.	20	16							
Paper-Card.	14	11				6	6		
PET	0	0				0	0		
Nylon	0	0				0	0		
Plastics	108	86				43	43		
Tetrapak	0	0							
Textile	62	50				25	25		
Total	**886**	**709**	**169**	**169**	**145**	**79**	**73**	**117**	**50**

Scenarios of Quetta for Economic Modelling

Table 67: Scenario-1 Quetta Waste Diversion

Scenario -1					
Waste Composition	**CW**	**DW**	**Compost**	**Recovery of Recyclables**	**LF Methane Capturing (Organic)**
Combustibles	261	52	52		
Diaper	0	0			
Elec.-Electro.	0	0			
Glass	15	3		3	
Hazardous	0	0			
Biodegradable	250	50	50		
Metals	2	0		0	
Non-Combust.	37	7			
Paper-Card.	27	5		5	
PET	0	0		0	
Nylon	0	0		0	
Plastics	114	23		23	
Tetrapak	0	0		0	
Textile	52	10		10	
Total	**758**	**152**	**102**	**42**	**202**

Table 68: Scenario-2 Quetta Waste Diversion

Scenario - 2						
Waste Composition	**CW**	**DW**	**Compost**	**Anaerobic Digestion**	**Recovery of Recyclables**	**LF Methane Capturing (Organic)**
Combustibles	261	104	52	52		
Diaper	0	0				
Elec.-Electro.	0	0				
Glass	15	6			6	
Hazardous	0	0				
Biodegradable	250	100	50	50		
Metals	2	1			1	
Non-Combust.	37	15				
Paper-Card.	27	11			11	
PET	0	0			0	
Nylon	0	0			0	
Plastics	114	45			45	
Tetrapak	0	0			0	
Textile	52	21			21	
Total	**758**	**303**	**102**	**102**	**84**	**316**

Table 69: Scenario-3 Quetta Waste Diversion

Scenario - 3							
Waste Composition	**CW**	**DW**	**Compost**	**Anaerobic Digestion**	**RDF**	**Recovery of Recyclables**	**LF Methane Capturing (Organic)**
Combustibles	261	157	78	78			
Diaper	0	0					
Elec.-Electro.	0	0					
Glass	15	9				9	
Hazardous	0	0					
Biodegradable	250	150	75	75			
Metals	2	1				1	
Non-Combust.	37	22					
Paper-Card.	27	16			8	8	
PET	0	0			0	0	
Nylon	0	0			0	0	
Plastics	114	68			34	34	
Tetrapak	0	0					
Textile	52	31			16	16	
Total	**758**	**455**	**153**	**153**	**58**	**68**	**269**

Table 70: Scenario-4 Quetta Waste Diversion

Scenario - 4									
Waste Composition	**CW**	**DW**	**Compost**	**Anaerobic Digestion**	**MBT**	**RDF**	**Recovery of Recyclables**	**LF Methane Capturing (Organic)**	**Incineration**
Combustibles	261	209	73	73	63				
Diaper	0	0							
Elec.-Electro.	0	0							
Glass	15	12					12		
Hazardous	0	0							
Biodegradable	250	200	70	70	60				
Metals	2	2					2		
Non-Combust.	37	30							
Paper-Card.	27	22				11	11		
PET	0	0				0	0		
Nylon	0	0				0	0		
Plastics	114	91				45	45		
Tetrapak	0	0							
Textile	52	42				21	21		
Total	**758**	**606**	**143**	**143**	**123**	**77**	**91**	**48**	**36**

Table 71: Scenario-wise GHG Emissions

Sr. No.	District	Emissions per ton of generated waste		Emissions per ton of collected waste		Emissions form yearly generated waste		Emissions from yearly collected waste	
		BC Emission (Kg/Tonnes)	Climate Impact from GHG Emissions (Kg of CO2 Eq/Tonnes	BC Emission (Kg/Tonnes)	Climate Impact from GHG Emissions (Kg of CO2 Eq/Tonnes)	BC Emission (Tonnes)	Climate Impact from GHG Emissions (Tonnes of CO2 Eq)	BC Emission (Tonnes)	Climate Impact from GHG Emissions (Tonnes of CO2 Eq)
Scenario-1									
1	Lahore	0.0010	488.5	0.0010	499.8	1.937	885240.7	1.9370	724627.1
2	Peshawar	0.0020	629.9	0.0034	684.9	1.110	434799.5	1.1096	221482.9
3	Quetta	0.0014	632.9	0.0022	688.7	0.617	288544.2	0.6171	190534.8
4	Karachi	0.002	570.48	0.003	574.72	10.304	2697742.5	10.304	2002083.2
Scenario-2									
1	Lahore	0.001	384.3	0.001	369.6	1.01	696413.9	1.014	535800.3
2	Peshawar	0.002	564.0	0.003	544.1	1.12	389282.6	1.123	175966.0
3	Quetta	0.001	528.3	0.002	516.2	0.47	240835.8	0.473	142826.4
4	Karachi	0.002	480.2	0.003	452.2	8.833	2270763.7	8.833	1575104.3
Scenario-3									
1	Lahore	0.009	309.9	0.199	276.6	15.807	561683.2	289.2	401069.6
2	Peshawar	0.005	519.1	0.178	448.3	3.440	358294.5	57.6	144977.9
3	Quetta	0.006	453.5	0.184	393.0	2.847	206729.6	50.9	108720.3
4	Karachi	0.018	469.5	0.358	437.7	85.561	2220309.0	1248.103	1524649.7
Scenario-4									
1	Lahore	0.028	219.1	0.253	163.1	50.126	397095.8	367.24	236482.23
2	Peshawar	0.01479	452.8	0.22065	306.8	10.2065	312547.3	71.3556	99230.704
3	Quetta	0.01707	348.2	0.22649	219.5	7.78106	158746.7	62.6639	60737.365
4	Karachi	0.038	377.0	0.404	312.1	181.159	1782982.4	1408.681	1087323.1

Table 72: Carbon Benefit for Each Scenario

CARBON BENEFITS POTENTIAL FROM COLLECTED WASTE					
LAHORE	**Carbon/ Environmental Benefit**	**Benefit as per Scenario**	**GHGs Emission Saving (kg/ton)**	**Mt CO2-eq**	**Rate (Rs.)/ Mt CO2-eq**
		Carbon Benefit - Scenario 1	329	0.329	464
		Carbon Benefit - Scenario 2	433	0.433	611
		Carbon Benefit - Scenario 3	507	0.507	715
		Carbon Benefit - Scenario 4	598	0.598	844
KARACHI	**Carbon/ Environmental Benefit**	**Benefit as per Scenario**	**GHGs Emission Saving (kg/ton)**	**Mt CO2-eq**	**Rate (Rs.)/ Mt CO2-eq**
		Carbon Benefit - Scenario 1	420	0.42	592.5
		Carbon Benefit - Scenario 2	511	0.511	720.8
		Carbon Benefit - Scenario 3	569	0.569	802.7
		Carbon Benefit - Scenario 4	652	0.652	919.7
QUETTA	**Carbon/ Environmental Benefit**	**Benefit as per Scenario**	**GHGs Emission Saving (kg/ton)**	**Mt CO2-eq**	**Rate (Rs.)/ Mt CO2-eq**
		Carbon Benefit - Scenario 1	219	0.219	309
		Carbon Benefit - Scenario 2	323	0.323	456

CARBON BENEFITS POTENTIAL FROM COLLECTED WASTE						
		Carbon Benefit - Scenario 3	398	0.398	561	
		Carbon Benefit - Scenario 4	503	0.503	710	
PESHAWAR	**Carbon/ Environmental Benefit**	**Benefit as per Scenario**	**GHGs Emission Saving (kg/ton)**	**Mt CO2-eq**	**Rate (Rs.)/ Mt CO2-eq**	
		Carbon Benefit - Scenario 1	221	0.221	312	
		Carbon Benefit - Scenario 2	287	0.287	405	
		Carbon Benefit - Scenario 3	332	0.332	468	
		Carbon Benefit - Scenario 4	398	0.398	561	

Table 73. MSW Sector alignment with SDGs

Sustainable Development Goals (SDGs)	Goal ID	Description	Alignment of Waste Sector with SDGs
SDG-1: (No Poverty)	1.4	The poor and vulnerable groups have equal right for economic resources and access to basic services	Equitable provision of cleanliness services in all urban and rural areas by WMCs. Integration of informal waste sector, i.e., scavengers and junkshops with formal system with better job opportunities
	1.B	Development of policy framework based on poor and gender sensitive development strategies to support investment in poverty eradication actions	This waste strategy formation at national level with the potential towards national strategy formation based on bottom-up approach. Special focus on informal sector (vulnerable poor group/ community) integration and enhancement of service area coverage.
SDG-2: (Zero Hunger)	2.4	Sustainable food production and implement resilient agriculture practices that increase the productivity and production	The organic compost production from organic waste can support the smart agriculture green practices by enhancing the soil fertility and reduce the farmers vulnerability index.
SDG-3: (Good Health & Wellbeing)	3.9	Reduce deaths and illnesses from hazardous chemicals, air, water, soil pollution and contamination	Waste diversion from open disposal and scientific landfill sites development will minimizes leachate seepage into ground water thus helps to reduce disease outbreaks, reduce toxic exposure to ground water.
	3.D	Strengthens capacity of Pakistan for early warning, risk reduction and management of national health risks	Efficient waste collection and service area coverage across all settlements. Controlled dumpsites at tehsil and district level are also mitigating the illegal waste dumping hazards.
SDG-4: (Quality Education)	4.4	Increase the employment and entrepreneurship opportunities with technical and vocational skills for adults and youth	Waste recovery, recycling and waste to resource production concepts have lot of potential for community based entrepreneurship opportunities for youth and adults
	4.7	Promote sustainable development and lifestyle and culture contributions for sustainable development	The behavior change towards waste minimization and prevention by the community will promote sustainable development through transition towards sustainable lifestyle
SDG-5: (Gender Equality)	5.5	Women's effective participation and equal opportunities for leaderships in decision making in economic life	Establishment of WMCs at divisional level across Punjab on the concept of corporate culture is providing equal job opportunists for women leadership at all tires of company's administration.
SDG-6: (Clean Water & Sanitation)	6.3	Improve water quality by eliminating dumping, minimizing release of hazardous chemicals and untreated wastewater,	Implementing waste diversion plans from landfilling and cost effective treatment of landfill leachate.
	6.4	Increase water-use efficiency across all sectors (including waste management) and ensure sustainable withdrawal of freshwater and reduce water scarcity	Switching from ground water/ freshwater hydrant to utilize ablution water and canal water to meet the water requirement for city furniture and monuments washing and city roads mechanical sweeping operations.
	6.6	Protect and restore water related ecosystems, i.e., rivers, lakes, wetland etc.	Efforts to minimize MSW including plastic, hazardous and e-waste entering into water related ecosystem.

	6.B	Local community participation in improving sanitation management	The role of local NGOs to engage the local community for waste reduction/ minimization and source segregations must be encouraged.
SDG-7: (Affordable & Clean Energy)	7.1	Ensure universal access to affordable, reliable and modern energy services	Promote concept of green energy from waste treatment, i.e., waste to RDF as coal substitute for power and cement industries, waste to biogas, waste to incineration for heat and electricity generation based on cost effective methods.
	7.2	Increase substantially the share of renewable energy in the global energy mix	Supports renewable energy from waste in the form of biogas, heat and electricity production.
	7.3	Double the global rate of improvement in energy efficiency	Minimize energy loss from waste leakages into environment, and waste burning at dumpsites along with waste diversion towards waste to energy (WtE) projects based on local waste composition.
SDG-8: (Decent Work and Economic Growth)	8.3	Promote policies that support job creations, entrepreneurship, innovation, and encourage growth of micro, small and medium size enterprises	This waste sector strategy will support the WMC's to engage local community through support of NGOs towards waste to recovery, and recycling programs through entrepreneurship at pilot/ small and medium size waste processing capacity plants.
	8.4	Improve global resource efficiency in consumption and production	Behavior change programs for waste reduction, and source segregations.
SDG-9: (Industries, Innovation and Infrastructure)	9.B	Support domestic technology development, research and innovation	Local interventions for waste collection (fleet modification/ manufacturing), treatment and disposal. Phytoremediation/ phytocapping techniques with native plant species for rehabilitation of old dumpsites to extract the heavy metals to minimize the seepage into ground/ nearby surface water.
SDG-10: (Reduce Inequalities)	10.B	Encourage official development assistance and financial flow including foreign direct investment	Local waste sector has potential to attract foreign direct investment opportunists for waste diversion (RDF, Compost, Biogas, WtE, LFG Recovery) to reduce its global climatic impact to sustain the sector.
SDG-11: (Sustainable Cities & Communities)	11.1	Ensure access for all basic services and upgrade slums	Waste sector is committed to provide equitable SWM services in all urban, semi urban including slum areas and rural areas at tehsil, district and division levels.
	11.6	Reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	Interventions in waste collection through route optimization, waste reduction, segregations at source, waste diversion for treatment and capturing/ recovering of LFG will support in reduction of per capita environmental impact.
	11.A	Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	WMCs are committed to provide equitable SWM services in all urban, semi urban and rural areas at regional level.
	11.B	Implement integrated urban policies climate mitigation, adaptation and resilience to disaster	Nature based solution (NBS) and adaptation approach support to minimize climatic impacts of dumpsite through rehabilitation and LFG recovery.
SDG-12: (Responsible Consumption & Production)	12.3	Halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses	Suthera Punjab Program is directly aligning with this target by ensuring Door to Door (DtD) SWM collection thus ensuring efficient organic/ kitchen waste collection. There is need to focus on consumption patterns by minimizing waste generation. Waste diversion for biogas and compost production from food waste will sustain the system.
	12.4	Environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their	WMCs can promote the waste diversion under guidelines of international treaties to minimize the environmental hazards of waste dumpsites. This can be achieved through waste diversion for treatment to reduce the landfill waste.

		adverse impacts on human health and the environment	Upgradation of open dumpsites into scientific landfill with lining system, leachate and gas collection mechanism support the minimal impacts to environment.
	12.5	Substantially reduce waste generation through prevention, reduction, recycling and reuse	WMCs should encourages citizens' behavior change towards waste prevention, Zero-waste initiatives, plastic, metal, glass, rag, and paper recycling programs, and innovation towards waste to resource such as compost, biogas, RDF, electricity, heat and fuel.
SDG-13: (Climate Action)	13.1	Strengthen climate resilience & adaptive capacity to climate related hazards and natural disasters	To deduce landfill waste through waste diversion approach for waste treatment will support waste related emissions reductions.
	13.2	Integrate climate change measures into national policies, strategies and planning	This waste strategy documents will support LG&CD department towards lowering the carbon footprint through waste diversion techniques.
	13.3	Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	Community engagement and public awareness campaigns will promote waste prevention, its segregations, reuse, recycling, and sustainable consumption.
SDG-14: (Life below Water)	14.1	Prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Enhancement in service area coverage will discourage the Illegal waste disposal into/ near water bodies specially the plastic waste. This will support to reduce marine debris from perspective of plastic waste.
SDG-17: (Partnerships for the Goals)	17.4	Assist in attaining long-term debt sustainability through coordinated policies aimed at fostering debt financing, debt relief and debt restructuring, as appropriate, and address the external debt of highly indebted poor countries to reduce debt distress	Open disposal sites of Pakistan are highlighted as global hotspots of methane emissions. Therefore, there is an opportunity for climate finance funding for LFG recovery and capture. The emissions reduction/ carbon savings along with climate justice can be used as tool to negotiate with IFIs for debt relief and restructuring for Pakistan.

Source: GOP (2025).

Table 74: Normalized Pairwise Matrix

Criteria	Operating Cost	Investment Cost	Emission Reduction Potential	Carbon Credit Potential	Market Sale	Land Requirement	Energy Requirement	Sound Technology	Environment Mitigation	Coherence with waste composition
Operating Cost	0.02	0.01	0.01	0.01	0.09	0.01	0.02	0.02	0.01	0.03
Investment Cost	0.07	0.03	0.01	0.01	0.07	0.01	0.02	0.02	0.01	0.03
Emission Reduction Potential	0.16	0.13	0.04	0.05	0.05	0.02	0.02	0.02	0.02	0.05
Carbon Credit Potential	0.16	0.13	0.04	0.05	0.09	0.02	0.02	0.03	0.02	0.05
Market Sale	0.07	0.10	0.21	0.15	0.27	0.16	0.27	0.28	0.18	0.48
Land Requirement	0.09	0.13	0.12	0.15	0.09	0.05	0.02	0.02	0.02	0.05
Energy Requirement	0.09	0.08	0.12	0.15	0.07	0.16	0.07	0.02	0.30	0.05
Sound Technology	0.11	0.13	0.21	0.15	0.09	0.26	0.34	0.09	0.18	0.03
Environment Mitigation	0.11	0.13	0.12	0.15	0.09	0.16	0.01	0.03	0.06	0.05
Coherence with waste composition	0.11	0.13	0.12	0.15	0.09	0.16	0.20	0.47	0.18	0.16

Table 75: Criterion Weights

Criteria	Criteria Weight
Operating Cost	0.02
Investment Cost	0.03
Emission Reduction Potential	0.06
Carbon Credit Potential	0.06
Market Sale	0.22
Land Requirement	0.07
Energy Requirement	0.11
Sound Technology	0.16
Environment Mitigation	0.09
Coherence with waste composition	0.18

Table 76: Consistency Ratios

Criteria Weight	Weighted Sum	Ratio
0.02	0.23	10
0.03	0.28	10
0.05	0.46	10
0.06	0.61	10
0.22	2.19	10
0.07	0.72	10
0.12	1.16	10
0.15	1.54	10
0.09	0.92	10
0.18	1.78	10

Table 77: Pairwise Decision Matrix

Criteria	Operating Cost	Investment Cost	Emission Reduction Potential	Carbon Credit Potential	Market Sale	Land Requirement	Energy Requirement	Sound Technology	Environment Mitigation	Coherence with waste composition
Compost	6	5.5	47	30	4	0.55	35	2	1	1
AD	12.2	11	29	10	10	0.42	150	3	2	2
Recycling	3	5.5	60	25	150	0.75	7.8	7	3	4
Incineration	7.5	29.4	20	3	20	0.17	586	4	7	7
RDF	20.5	5.5	15	5	20	0.35	250	6	6	6
MBT	17	15	40	5	20	0.21	150	5	4	3
LFG	5	1.5	30	25	5	1.65	25	1	5	5

Table 78: Normalized Pairwise Decision Matrix

Criteria	Operating Cost	Investment Cost	Emission Reduction Potential	Carbon Credit Potential	Market Sale	Land Requirement	Energy Requirement	Sound Technology	Environment Mitigation	Coherence with waste composition
Compost	0.50	1.00	0.78	1.00	0.03	0.31	0.22	0.50	1.00	1.00
AD	0.25	0.50	0.48	0.33	0.07	0.40	0.05	0.33	0.50	0.50
Recycling	1.00	1.00	1.00	0.83	1.00	0.23	1.00	0.14	0.33	0.25
Incineration	0.40	0.19	0.33	0.10	0.13	1.00	0.01	0.25	0.14	0.14
RDF	0.15	1.00	0.25	0.17	0.13	0.49	0.03	0.17	0.17	0.17
MBT	0.18	0.37	0.67	0.17	0.13	0.81	0.05	0.20	0.25	0.33
LFG	0.60	3.67	0.50	0.83	0.03	0.10	0.31	1.00	0.20	0.20