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CARBON CREDIT POTENTIAL OF INTEGRATED SOLID WASTE MANAGEMENT: A CASE STUDY OF BAHAWALPUR, PAKISTAN

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Abstract

Rapid urbanization and inadequate waste management have positioned Pakistan's municipal solid waste sector as a critical source of greenhouse gas (GHG) emissions, particularly methane from uncontrolled dumping. This study focuses on Bahawalpur under the Punjab Intermediate Cities Improvement Investment Program (PICIIP) and the DREAMS initiative, where Integrated Solid Waste Management (ISWM) is introduced as a model for climate-aligned urban services. Using the U.S. EPA's Solid Waste Emissions Estimation Tool (SWEET) and IPCC Tier 1–2 methodologies, baseline emissions were assessed under a Business-as-Usual (BAU) scenario and compared with a suite of project interventions including composting, material recovery, engineered landfills with methane capture, anaerobic digestion, and improved waste logistics. Results show cumulative reductions of approximately 1.72 million tCO_2e between 2028 and 2050, generating a potential revenue of USD 5.15–20.6 million through carbon crediting. The project's peak mitigation benefits align with the operational maturity of landfill gas capture, while interventions such as composting and recycling reinforce circular economy objectives and co-benefits for health, employment, and resource recovery. Overall, Bahawalpur's ISWM demonstrates both technical feasibility and financial viability, presenting a replicable model for Pakistan's intermediate cities to access carbon finance and achieve long-term sustainability.

1 Introduction

Rapid population growth and limited formal waste management have created critical challenges for Pakistan's cities. Unregulated dumping and open burning are prevalent, exacerbating public health risks and contributing disproportionately to methane and other greenhouse‑gas emissions. Worldwide, nearly 40 % of waste is disposed of in open dumpsites and only about 36 % of the population in low‑income countries is served by waste collection. Pakistan's urban areas exhibit similar patterns; municipal budgets and institutional capacity remain insufficient to deliver sustainable waste services. As a result, solid waste management has emerged as a priority sector under the country's climate strategies. The Government of Pakistan's Nationally Determined Contributions (NDC)

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explicitly highlight the waste sector's potential for high‑impact methane reduction, recognising that interventions such as organic waste composting, landfill gas capture and recycling can generate measurable emission reductions and carbon credits.

This paper focuses on Bahawalpur, a medium‑sized city in Punjab and the twelfth largest in Pakistan. Under the Asian Development Bank's Developing Resilient Environments and Advancing Municipal Services (DREAMS) initiative—part of the Punjab Intermediate Cities Improvement Investment Program (PICIIP)—Bahawalpur's solid waste system is being redesigned to meet environmental and climate objectives. The Bahawalpur Waste Management Company (B‑WMC), a non‑profit entity established in 2013, holds a service and asset management agreement that grants it operational autonomy to develop integrated waste collection, transport, recovery, treatment and disposal services. Planned investments include engineered sanitary landfills, materials recovery facilities and composting units to reduce reliance on open dumping and increase recycling and treatment rates. By aligning waste services with low‑emission development, the city aims to unlock international carbon finance opportunities, positioning Bahawalpur as a model for sustainable urban waste management in Pakistan.

1.1 Objectives of the Study

The study aims to evaluate greenhouse gas (GHG) emissions reductions and quantify potential carbon credits through the implementation of Integrated Solid Waste Management (ISWM) in Bahawalpur. By establishing a scientifically sound emissions baseline and analyzing interventions under the DREAMS project, it seeks to determine how practices such as composting, material recovery, engineered landfills with methane capture, and improved collection systems can reduce GHG emissions.

1.2 Selection of Target City

Bahawalpur's selection for pilot ISWM implementation is based on its substantial waste output (524 tons/day projected for 2028), lack of a sanitary disposal facility, and readiness through PRF and PICIIP. The city's informal waste sector comprising waste pickers, itinerant buyers, junkshop owners, and scrap dealers currently recovers around 27% of the total waste, diverting some 35,000 tons per year and generating roughly PKR 4.7 billion in revenue. This recovery decreases landfill-bound waste and reduces methane emissions, aligning with Pakistan's NDC objectives. However, informal workers face unsafe conditions and are excluded from formal plans and carbon credit schemes. By investing in composting, material recovery, landfill gas capture, and anaerobic digestion, Bahawalpur can generate verifiable emissions reductions that qualify under CDM, VERRA, or Article 6 frameworks, opening access to climate finance. Integrating these initiatives would set a precedent for other intermediate cities in Punjab to pursue low-carbon development. Estimation Approach for Measuring GHG Emissions

Quantification of greenhouse gas (GHG) emissions from solid waste relies on internationally recognized methodologies, particularly the IPCC guidelines for National GHG Inventories (IPCC, 2006). These guidelines recommend tiered approaches, with Tier 1 using default emission factors, Tier 2 applying country-specific data, and Tier 3 employing direct measurement systems. The First Order Decay (FOD) model, which estimates methane (CH_4) from the degradable organic carbon content of waste, is central to the IPCC framework. Project-level standards further refine these methodologies. The UNFCCC's CDM methodologies (e.g., AM0025, ACM0022) provide quantification pathways for composting and alternative waste treatments (UNFCCC, 2020). Similarly, voluntary standards such as Verra's Verified Carbon Standard (VCS) and the Gold Standard require baseline scenario analysis, waste characterization, and rigorous Monitoring, Reporting, and Verification (MRV) systems to ensure the credibility of claimed reductions (Verra, 2021; Gold Standard, 2022). In Pakistan, these frameworks are increasingly relevant as provinces like Punjab pursue methane capture and waste diversion to access carbon markets. In the Bahawalpur Integrated Solid Waste Management (ISWM) project, the Solid Waste Emissions Estimation Tool (SWEET)—developed by the U.S. Environmental Protection

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Agency (US-EPA)—was applied to model both Business-as-Usual (BAU) and project scenarios. Using Tier 2 methodologies, SWEET incorporated Bahawalpur's Waste Analysis and Characterization Study (WACS) data, including methane generation potential (170 m^3 CH_4/ton), decay rates adapted for semi-arid conditions, and landfill gas (LFG) capture efficiencies projected to reach 75% by 2040. SWEET's dynamic Excel-based modeling enabled projections of CO_2-equivalent emissions, accounting for collection, transport, composting, recycling, and waste-to-energy processes (US-EPA, 2019). While Tier 3 offers higher accuracy through continuous monitoring, it remains resource-intensive and less feasible in developing contexts. Thus, combining Tier 1 and Tier 2 methods ensures both practicality and compliance with international carbon crediting requirements. Both Verra and Gold Standard encourage Tier 2+ approaches to enhance environmental integrity and MRV compatibility (Verra, 2021; Gold Standard, 2022).

1.3 Baseline Emission Assessment

The Business-as-Usual (BAU) scenario provides the benchmark for calculating potential GHG reductions, reflecting the continuation of existing waste management practices such as uncontrolled open dumping, minimal recycling, absence of landfill gas recovery, and reliance on diesel-powered transport. Baseline data were drawn from the Waste Analysis and Characterization Study (WACS, 2022), which recorded a generation rate of 477 tons per day with approximately 68% organic content. Additional inputs included estimates from the informal recycling sector, which accounts for about 27% recovery of plastics, metals, and cardboard, along with demographic projections used to model increasing waste loads through 2050. Using the IPCC's First-Order Decay (FOD) model, the SWEET tool calculated methane emissions from unmanaged decomposition, supplemented with emissions from open burning and transport. These results indicate that, without intervention, baseline emissions are projected to rise significantly by 2050 (IPCC, 2006; US-EPA, 2019).

1.3.1 Process Mapping

A detailed process mapping of Bahawalpur's waste management system was conducted to track waste from generation to final disposal, identify emission hotspots, and analyze current gaps in GHG control. The application of standardized quantification tools like SWEET enabled accurate estimation of GHG reductions, energy savings, and material recovery across each intervention. This mapping revealed major hotspots at:

- Organic waste decomposition in open dumps (high CH_4 emissions),
- Open burning of uncollected waste (CO_2 and black carbon emissions),
- Inefficient waste transport (fossil fuel CO_2 emissions).

The ISWM introduces emission reduction strategies through:

- Source segregation and organized recycling at MRFs,
- Composting of organic waste to avoid anaerobic decomposition,
- Engineered landfills with Landfill Gas (LFG) capture systems,
- Fleet optimization and fuel-efficient transport systems.

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1.3.2 Waste Value Chain in Business as Usual (BAU)

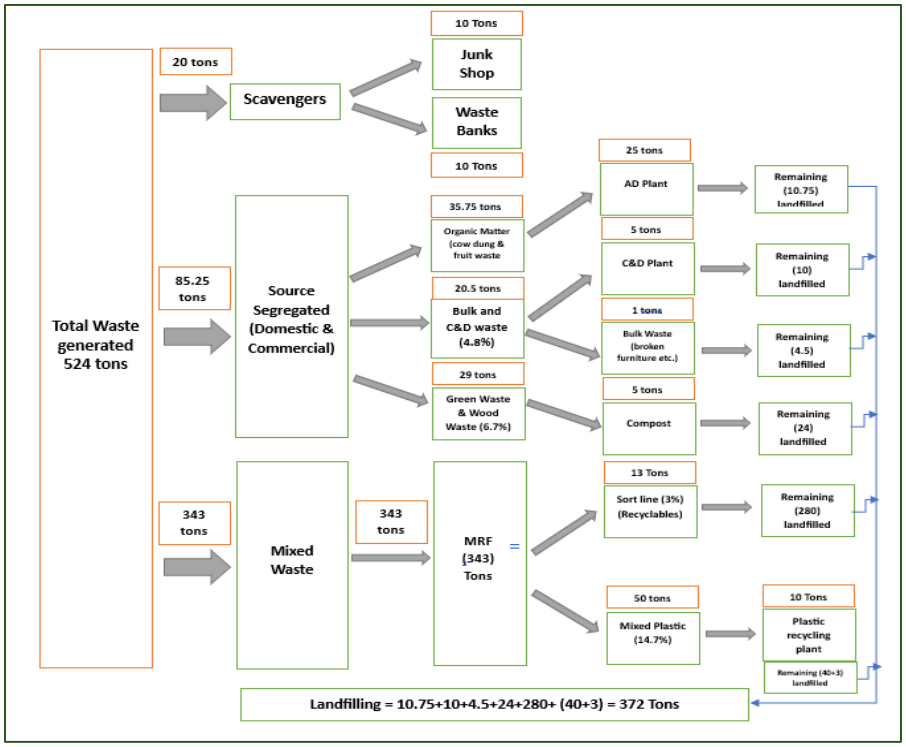
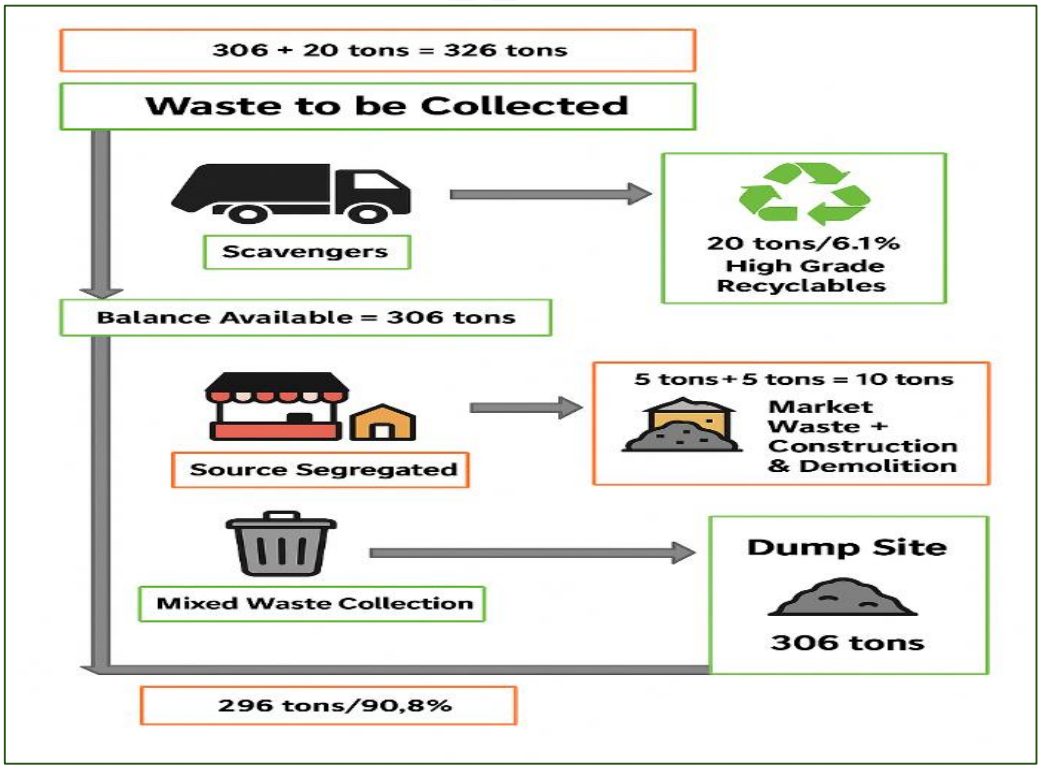


Figure 1: A: Waste Value Chain in BAU



B: Figure 2: Waste Flow Diagram with Project

In the context of carbon quantification, process mapping of the Waste Value Chain under the BAU) scenario is essential for identifying emission sources and estimating baseline GHG emissions. The BAU model for Bahawalpur reflects the operational reality of waste generation and management as of 2022, providing critical input data for emissions

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estimation tools like the IPCC guidelines or SWEET. The population in the served area, spread across 18 Union Councils (UCs), is projected at 685,092, generating approximately 376 tons of waste per day, based on a per capita waste generation rate of 0.55 kg/day (WACS, December 2022). In contrast, the unserved population (103,358 in UCs 6, 20, and 21) contributes an additional 56 tons/day. Out of the total waste generated in the served area, 306 tons/day is collected by B-WMC, while approximately 20 tons/day is informally removed by scavengers, typically before formal collection.

Waste Value Chain with Project Interventions

The 2028 project scenario marks a shift in Bahawalpur's waste value chain, introducing formalized interventions to increase waste diversion, resource recovery, and methane reduction. With a projected population of 924,315 generating about 524 tons/day, around 20 tons/day will remain informally recovered, while 428 tons/day will be formally managed at 85% collection efficiency (Figure 5). Planned interventions include door-to-door collection, segregation at MRFs, composting, anaerobic digestion, recycling, sanitary landfilling, and C&D waste recovery.

1.3.3 Waste Flow in Informal Chain

The informal sector plays a crucial role in Bahawalpur's recycling economy by diverting significant volumes of recyclables from disposal, though without undertaking recycling themselves. Households generate about 33,642 tons of recyclables annually, part of which is collected by waste pickers from streets, bins, and dumpsites. These materials move to small junk shops (Stage 1 recyclers) where basic sorting and resale occur, and also through itinerant buyers who collect directly from households using bicycles or carts. Ultimately, waste flows to large scrap dealers (Stage 2 recyclers) who conduct advanced segregation, baling, and supply to industries. This chain illustrates the scale of informal recovery, highlights leakages in the value chain, and underscores the potential benefits of integrating informal actors into formal waste management and climate mitigation frameworks.

1.4 BAU Emissions

Under the Business-as-Usual (BAU) scenario, Bahawalpur's waste system is marked by fragmented collection, informal recovery, and environmentally damaging open dumping. Baseline emissions are dominated by methane from uncontrolled anaerobic decomposition, with SWEET model outputs showing 86,925 tCO_2e/year in 2027, rising to nearly 300,576 tCO_2e/year by 2050 if no interventions occur (Figure 3: Total Emissions BAU Scenario). Waste volumes are projected to grow from 477 tons/day in 2025 to over 990 tons/day by 2050, with about 68% biodegradable content, making the system highly methane-intensive. The SWEET model applies IPCC Tier 2 methods for landfill methane, using site-specific parameters such as decay rates, Methane Correction Factors (0.4–0.6), and oxidation coefficients, while Tier 1 defaults are used for fuel combustion in transport and handling equipment. Although the informal sector diverts roughly 24% of recyclables, its impact is not claimable in carbon markets due to poor traceability and lack of MRV systems. Baseline trajectories also indicate rising emissions of PM_{10} and black carbon, primarily from landfills, LFG combustion, and waste burning (Figure 5A: Baseline PM_{10} Emissions by Source; Figure 5B: Baseline Black Carbon Emissions by Source). These trends underscore the urgency of interventions such as dumpsite capping, formal recovery systems, and infrastructure upgrades to mitigate emissions and improve air quality.

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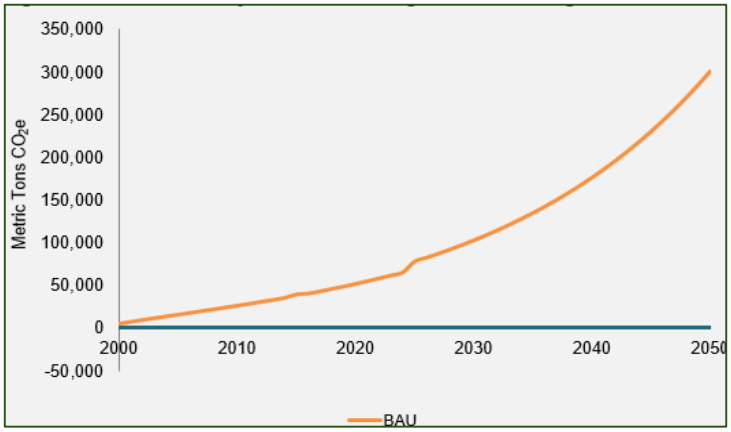


Figure 3: Total Emissions BAU Scenario including CO_2, BC, CH_4, Organic Carbon

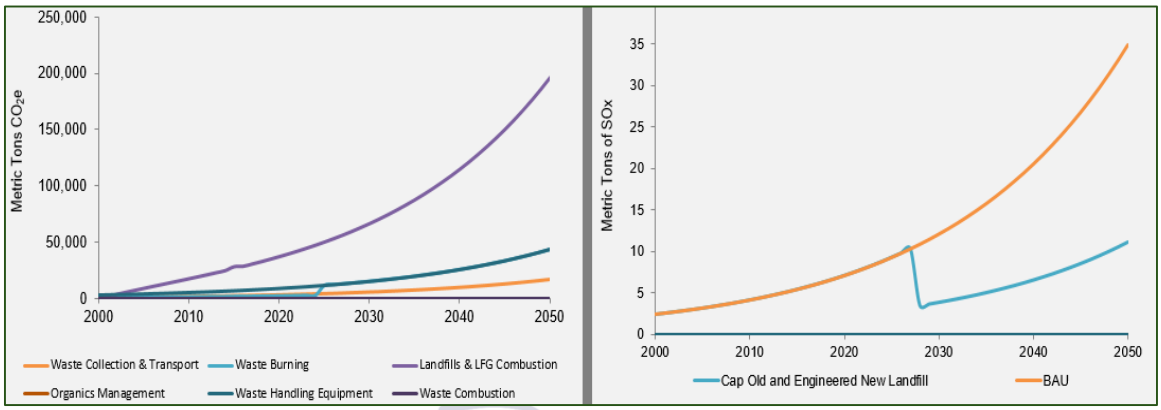


Figure 4: a: Baseline All Climate Forcing Emission By source (CH4, BC, OC, NOx, CO2), b: Combustion Related Sulfur Dioxide Emission by Scenario (Sector Specific Emission Sources 2000 to 2050)

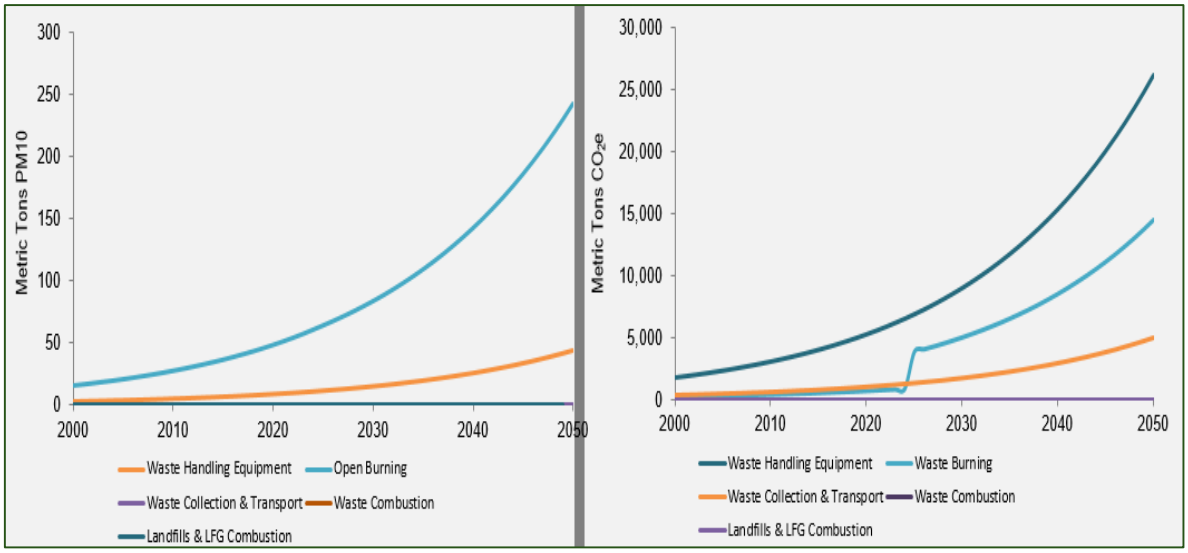


Figure 5A: Baseline PM10 Emission by Source, Figure 5B: Baseline Black Carbon Emission By source over time

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1.5 Project Interventions Emissions

The Bahawalpur ISWM introduces integrated interventions to reduce emissions, enhance resource recovery, and formalize waste management. Core measures include door-to-door (D2D) collection with sealed containers and a fuel-efficient CNG fleet (Figure 6: CO_2 & NOx Emissions; Figure 7: SO_2 & PM_{10} Emissions), the establishment of a Material Recovery Facility (MRF) for mechanized sorting and integration of informal workers, and composting of organic waste that diverts methane-intensive materials while producing fertilizer (Figure 8: N_2O & CO_2 Emissions; Figure 9: CH_4 & Total Emissions;

Figure 14: Organic Carbon Emissions).

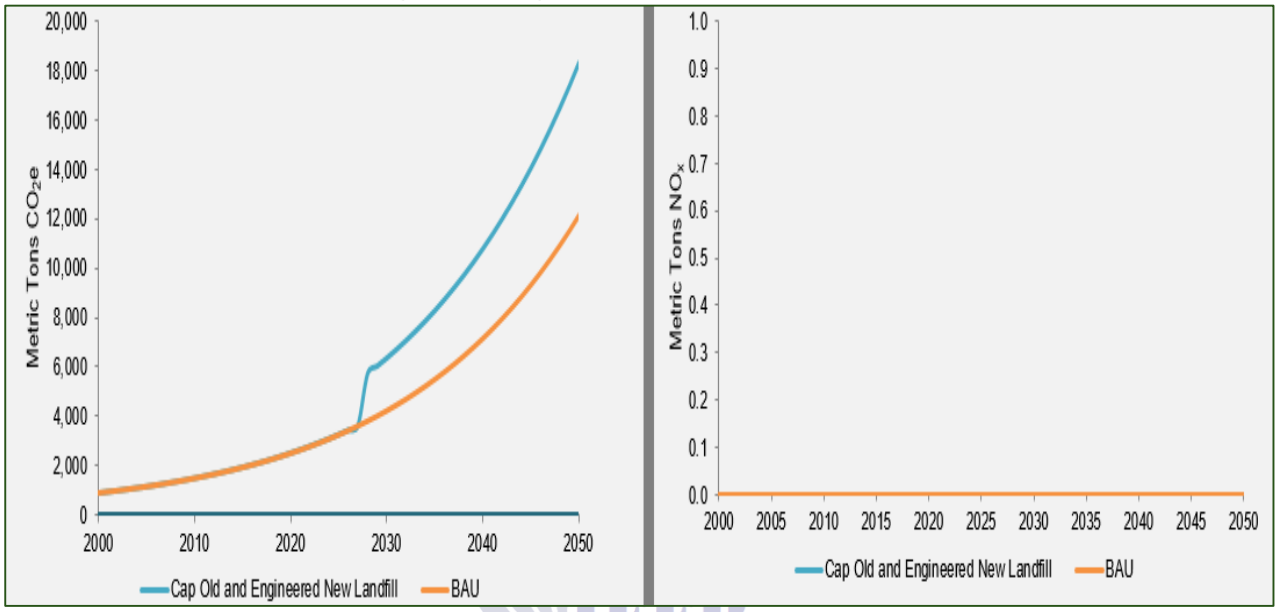


Figure 6: A: CO_2 and B: NO_x Emissions by Scenario 2000-2050 (Transportation Sector Emission Summaries 2000 to 2050)

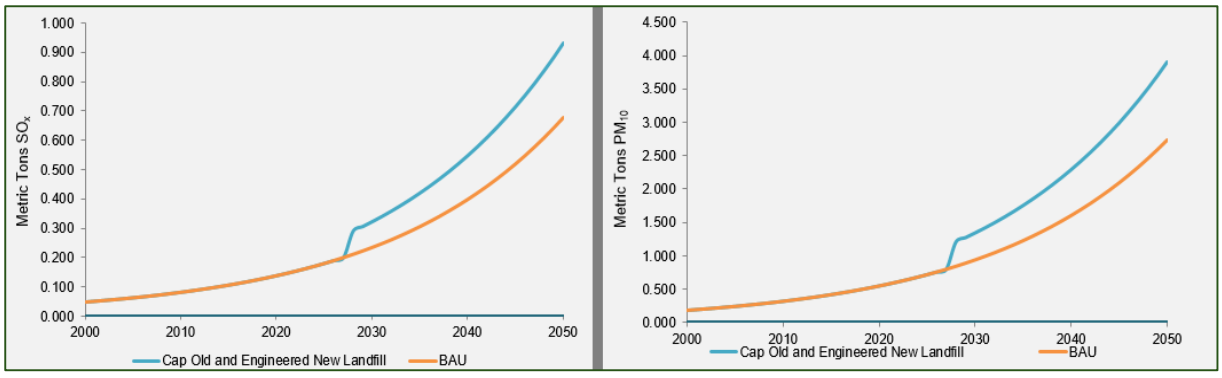


Figure 7: SO_2 and PM_{10} Emissions by Scenario

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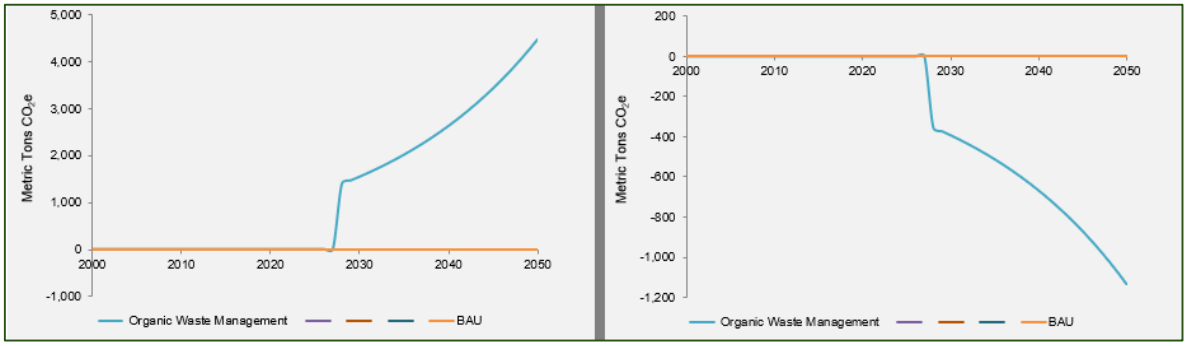


Figure 8: A; N2O Emission equivalent to CO2e by scenario from organic waste management, B; CO2 Emission by Scenario from Organic Waste Management (with Project Scenario)

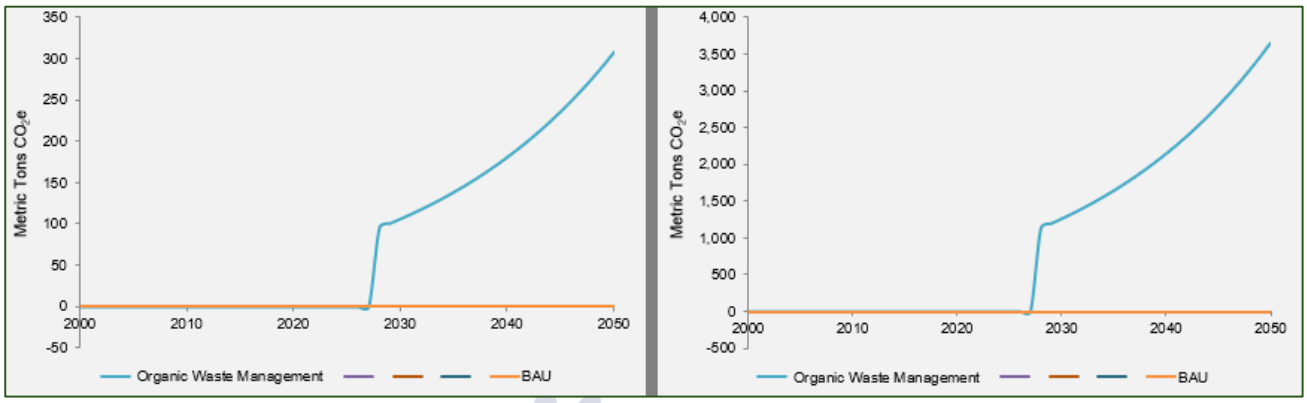


Figure 9: CH4 Emissions by Scenario from Organic Waste Management B: Total Emission by Scenario from Organic waste

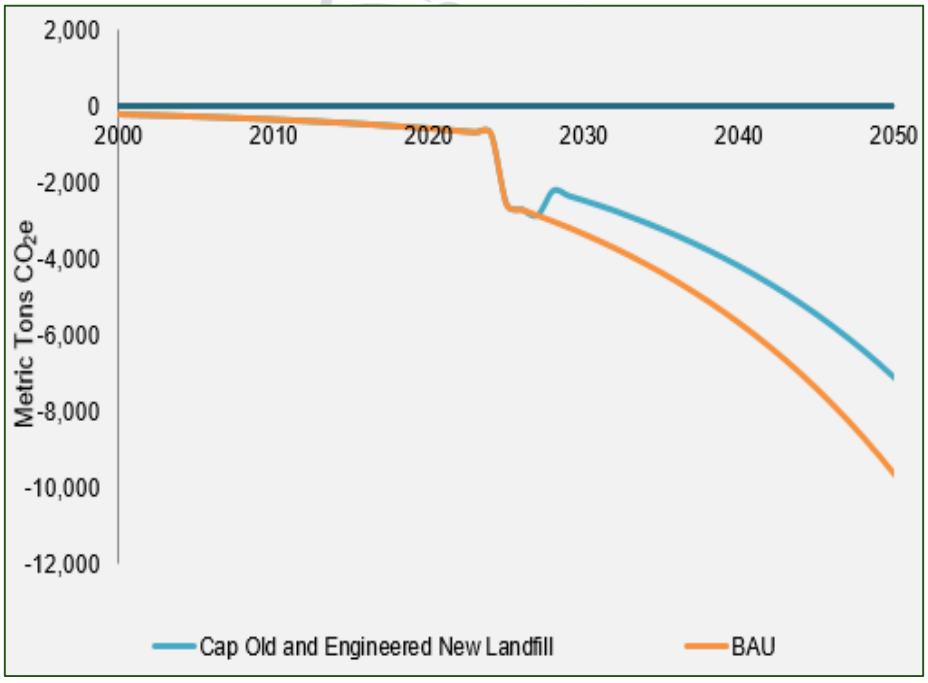


Figure 10: Scenario Comparison of Organic Carbon Emissions

Early interventions include closure and capping of the existing dumpsite with passive flaring (Figure 11: Old Dumpsite Methane Emissions; Figure 12: New Engineered Landfill Methane Emissions), alongside the development of a new engineered landfill with gas capture infrastructure achieving ~60% methane

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recovery by 2033 (Figure 13: Methane Emissions Comparison). Complementary measures include anaerobic digestion (AD) plants for biogas recovery, C&D waste recycling to reduce landfill volume and hauling emissions, and a plastic crushing unit to lower transport emissions and improve recycling market value (Figure 14: Landfill Fire & PM_{10} Emissions).

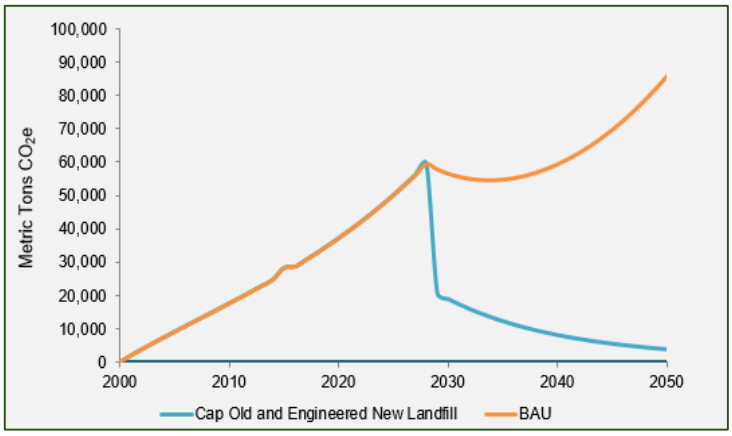


Figure 11: Bhinda Daakhli Dumpsite Methane Emission by Scenario

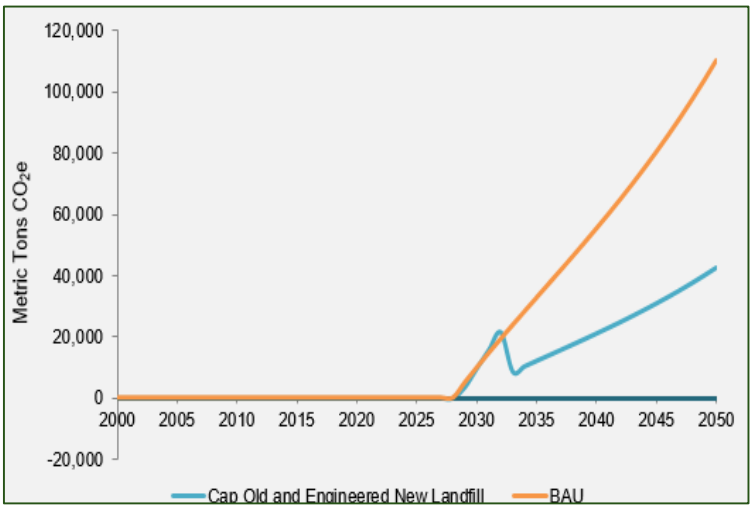


Figure 12: New Engineered Landfill Methane Emissions by Scenario

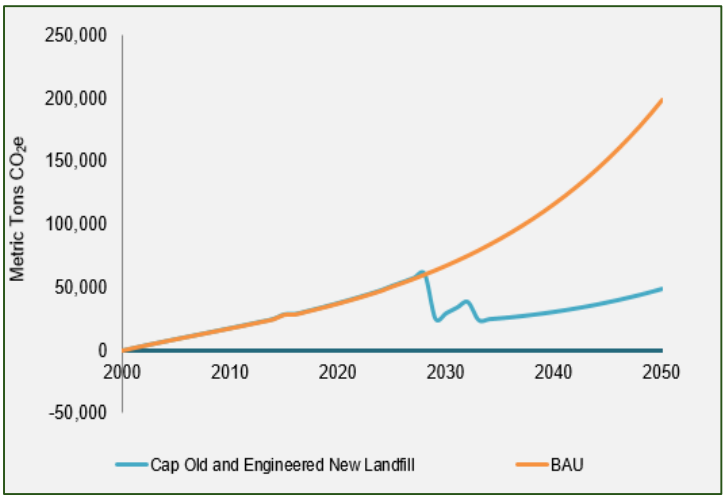


Figure 13: Scenario Comparison of Methane Emissions Over Time

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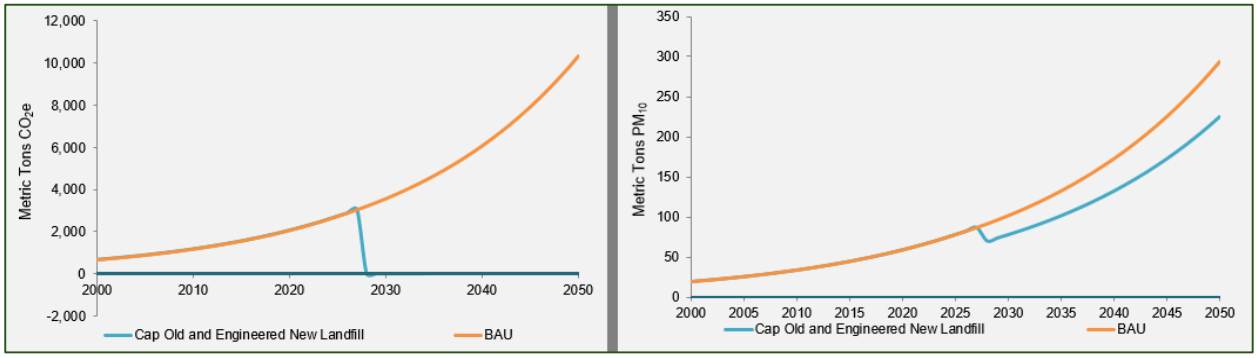


Figure 14: A: Climate Forcing from Landfill/Dumpsite Fire Emissions by Scenario B: PM10 Emission from waste burning Emission by Scenario

Crucially, the project formalizes the informal sector, integrating waste pickers into structured MRF operations with PPE, IDs, and traceable recovery systems. This eliminates open burning and significantly reduces climate-forcing pollutants (Figure 15: Climate Forcing from Waste Burning).

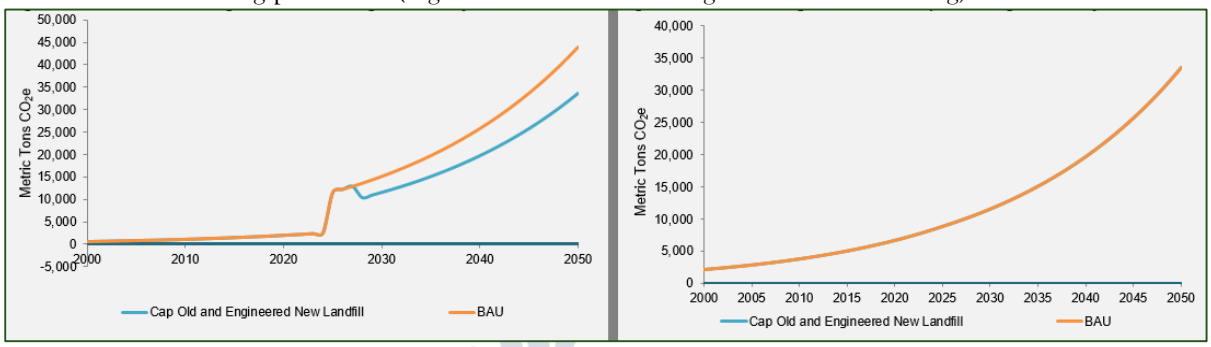


Figure 15: A: Total Climate Forcing from waste burning Emission by Scenario B: Climate Forcing Emission from Open burning of waste by scenario

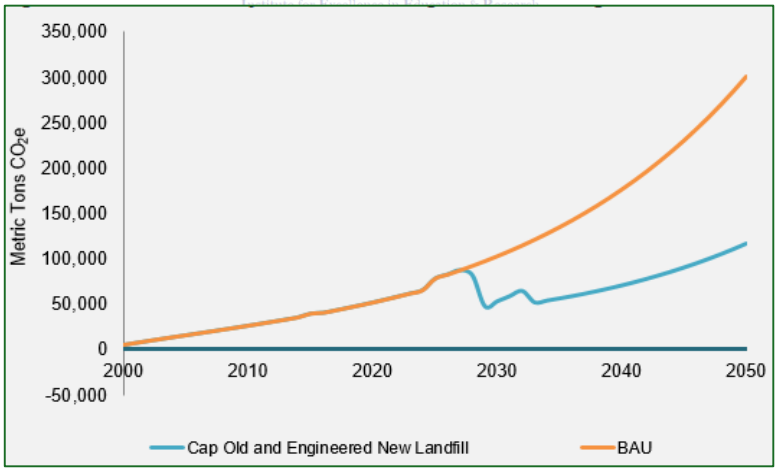


Figure 16: Total Emission by Scenario including CO2, BC, CH4, organic carbon

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2 Revenue Estimation of Carbon Credits

The Bahawalpur Integrated Solid Waste Management (ISWM) project presents a major opportunity to generate verifiable carbon credits by reducing emissions of methane (CH_4), carbon dioxide (CO_2), and black carbon. These reductions are achieved through interventions such as landfill gas (LFG) capture, dumpsite closure and flaring, composting, MRF-based recycling, and fuel-efficient logistics, modelled in the SWEET tool under IPCC Tier 1 and Tier 2 methodologies (IPCC, 2006; US-EPA, 2019).

2.1 Emission Reductions Across Interventions

The largest share of reductions stems from methane capture at the new engineered landfill (operational in 2033) and the capped dumpsite (from 2028). Composting (30–40 tons/day) further avoids methane emissions by diverting organic waste, while material recovery displaces emissions from virgin production (WACS, 2022). Smaller but cumulative reductions come from C&D recycling and plastic crushing. Collectively, reductions span Scope 1 (direct emissions), Scope 2 (facility energy use), and Scope 3 (avoided upstream production/transport). By 2050, total avoided emissions are projected at 4.26 million tCO_2e relative to BAU (Verra, 2021).

Table 1: GHG Emission Reduction

Year	Business as usual	Project Interventions: ISWM	Project Interventions: GHG reductions
2025	77,750	77,750	0
2026	82,224	82,224	0
2027	86,925	86,925	0
2028	91,868	81,200	10,668
2029	97,068	47,534	49,534
2030	102,539	53,774	48,765
2031	108,298	60,034	48,263
2032	114,360	66,347	48,013
2033	120,744	64,016	56,728
2034	127,468	68,723	58,745
2035	134,551	73,584	60,967
2036	142,013	78,617	63,396
2037	149,876	83,840	66,036
2038	158,162	89,272	68,890
2039	166,894	94,929	71,965
2040	176,098	100,832	75,266
2041	185,800	107,000	78,800
2042	196,026	113,451	82,576
2043	206,807	120,206	86,601
2044	218,173	127,287	90,886
2045	230,155	134,715	95,440
2046	242,789	142,512	100,277
2047	256,108	150,701	105,407
2048	270,153	159,308	110,845
2049	284,961	168,357	116,604
2050	300,576	177,875	122,701

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2.2 Early Phase (2028–2032)

Emission reductions come from dumpsite capping, composting of segregated organics, and partial MRF operation. Annual reductions range 10,700–50,300 tCO_2e (average ~30,000). Figure 17 shows the revenue and credit issuance trajectory.

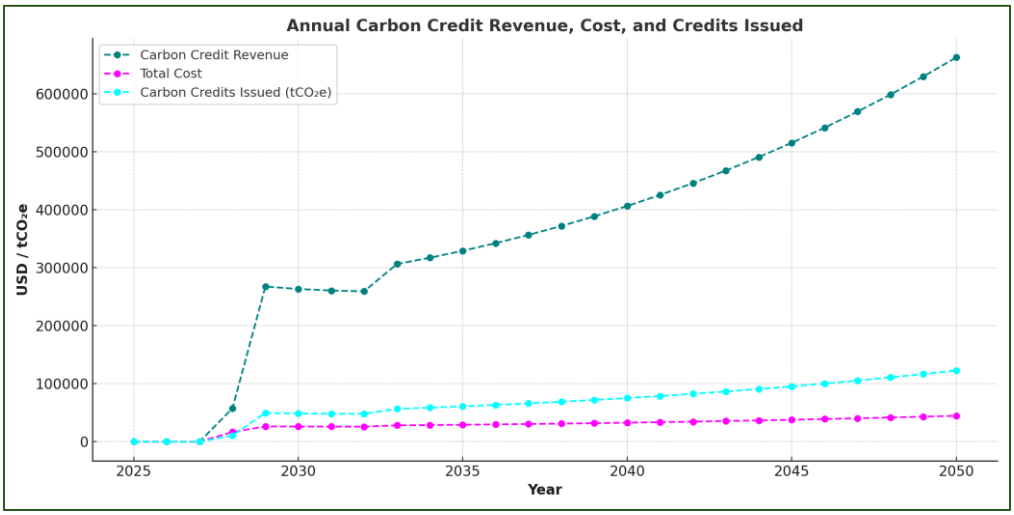


Figure 17: Projected Revenue, Costs, and Carbon Credit Issuance from Landfill Methane Capture (2028–2050)

2.3 Peak Credit Phase (2033–2045)

With landfill gas capture fully operational, average reductions reach 112,141 tCO_2e/year. This is the project's most productive crediting window, supported by composting and expanded MRF operations (Gold Standard, 2022).

2.4 Stabilization Phase (2046–2050)

As gas yields decline, reductions taper but remain significant, averaging **137,400 tCO_2e/year** across the crediting period. Emissions stabilize below 100,000 tCO_2e annually, demonstrating long-term MRV credibility (UNFCCC, 2020).

2.5 Revenue Potential

At conservative pricing of USD 3–8 per tCO_2e, the project could generate USD 5.2–13.8 million over 23 years. With co-benefit certifications (e.g., Verra SD VISta, Gold Standard), premium pricing of USD 15–20 per tCO_2e is achievable, linked to SDG impacts such as health, gender equality, decent work, and climate action.

Financial analysis shows in table 2:

- NPV (2028–2050): USD 1.36 million (discount rate 12.3%)
- Total Net Revenue: USD 8.52 million
- Cost-Benefit Ratio: 11.6 (every $1 spent yields $11.6)
- Payback period: 2028 (first year of issuance)

Carbon revenue can be ring-fenced for O&M of LFG systems, scaling composting, digital MRV, and institutional capacity building (Verra, 2023). The registration and validation of the Bahawalpur ISWM project under the Verra Verified Carbon Standard (VCS) framework involves both registry fees and external costs. At the registration stage, Verra charges include account opening (USD 1,500), pipeline listing (USD 1,500 per request), and a registration review fee (USD 3,750 per request) (Verra, 2023). In parallel, external expenditures are incurred for the preparation of the Project Design Document (PDD) and feasibility and baseline studies, typically ranging between USD 30,000 and 150,000, depending on project complexity and data availability (Hamrick & Gallant, 2018). During the validation stage, no additional Verra fee is required beyond the registration review; however, the project must undergo a third-party validation audit conducted by an accredited Validation and Verification Body (VVB), which generally costs between USD

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15,000 and 25,000 (World Bank, 2021). These combined costs highlight the need for adequate upfront financing to ensure compliance with international carbon crediting requirements and to establish the project's eligibility for verified emissions reductions in global markets.

Table 2: Carbon Costs and Revenue streams

Year	BAU	Post Interventions	GHG reductions	Revenue (USD)	Verification cost (USD)	Issuance fee (USD)	Total cost (USD)	Net Revenue (USD)
2025	77,750	77,750	0	0	-	-	-	-
2026	82,224	82,224	0	0	-	-	-	-
2027	86,925	86,925	0	0	-	-	-	-
2028	91,868	81,200	10,668	57,608	14,000	2,667	16,667	40,941
2029	97,068	47,534	49,534	267,484	14,000	12,384	26,384	241,101
2030	102,539	53,774	48,765	263,334	14,000	12,191	26,191	237,143
2031	108,298	60,034	48,263	260,622	14,000	12,066	26,066	234,556
2032	114,360	66,347	48,013	259,272	14,000	12,003	26,003	233,269
2033	120,744	64,016	56,728	306,332	14,000	14,182	28,182	278,150
2034	127,468	68,723	58,745	317,223	14,000	14,686	28,686	288,537
2035	134,551	73,584	60,967	329,221	14,000	15,242	29,242	299,979
2036	142,013	78,617	63,396	342,338	14,000	15,849	29,849	312,489
2037	149,876	83,840	66,036	356,592	14,000	16,509	30,509	326,083
2038	158,162	89,272	68,890	372,007	14,000	17,223	31,223	340,785
2039	166,894	94,929	71,965	388,611	14,000	17,991	31,991	356,620
2040	176,098	100,832	75,266	406,436	14,000	18,817	32,817	373,620
2041	185,800	107,000	78,800	425,521	14,000	19,700	33,700	391,821
2042	196,026	113,451	82,576	445,908	14,000	20,644	34,644	411,264
2043	206,807	120,206	86,601	467,645	14,000	21,650	35,650	431,995
2044	218,173	127,287	90,886	490,782	14,000	22,722	36,722	454,061
2045	230,155	134,715	95,440	515,378	14,000	23,860	37,860	477,518
2046	242,789	142,512	100,277	541,495	14,000	25,069	39,069	502,426
2047	256,108	150,701	105,407	569,199	14,000	26,352	40,352	528,847
2048	270,153	159,308	110,845	598,562	14,000	27,711	41,711	556,851
2049	284,961	168,357	116,604	629,663	14,000	29,151	43,151	586,512
2050	300,576	177,875	122,701	662,583	14,000	30,675	44,675	617,908

Sources: 1. Verra. "VCS Standard Fee Schedule v4.0." May 2023. https://verra.org/wp-content/uploads/2023/05/VCS-Standard-Fee-Schedule_v4.0.pdf , 2. U.S. Environmental Protection Agency. "Landfill Methane Outreach Program (LMOP)." Accessed June 22, 2025. https://www.epa.gov/lmop

2.6 Sensitivity Analysis

The project's performance is most sensitive to methane recovery efficiency (assumed 60%). A 10% drop could reduce credits by 120,000 tCO_2e. Composting efficiency and MRF recovery rates also influence credit eligibility. Despite these risks, projections remain conservative at 730,000–800,000 tCO_2e over 23 years, consistent with global benchmarks in Brazil and India (Gold Standard, 2022; UNFCCC, 2020).

Figure 18: Heat Map of Profit and Discount Rate Sensitivity shows positive NPV across all scenarios, ranging from USD 784,000 (worst case) to USD 4.2 million (best case), confirming strong financial resilience.

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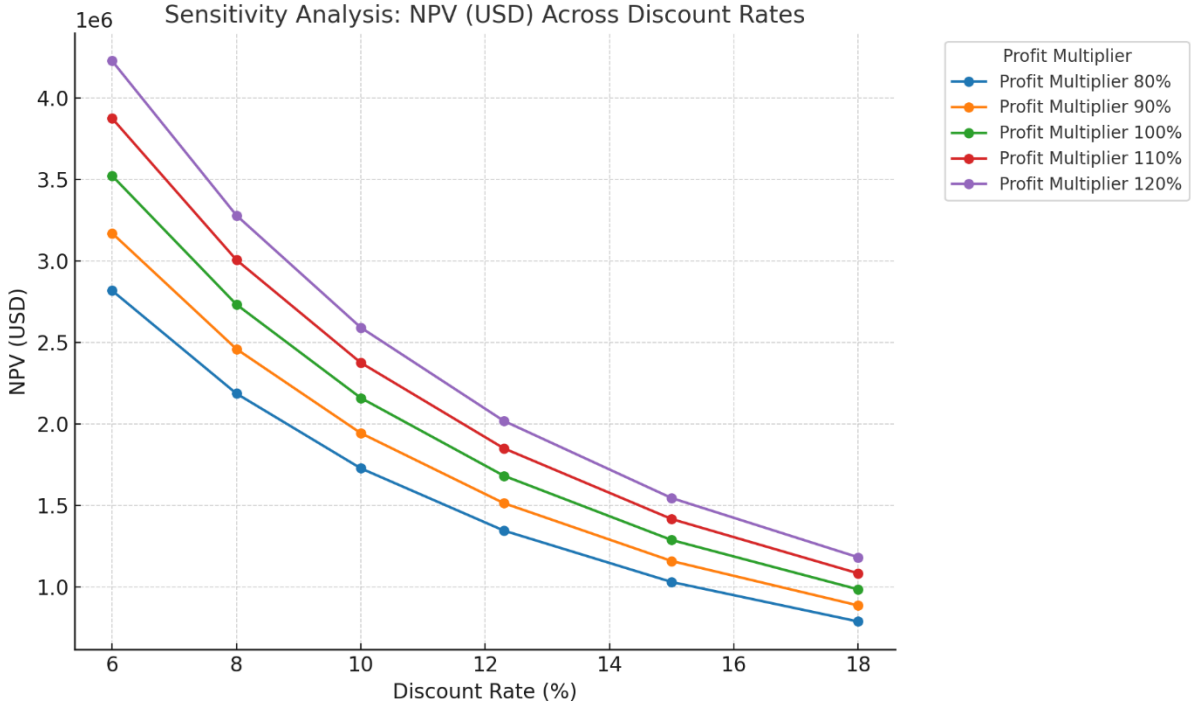


Figure 18: Heat Map of Profit and Discount Rate Sensitivity

The sensitivity analysis shows that across all scenarios of profit multipliers (80–120%) and discount rates (6–18%), the project maintains a positive NPV ranging from USD 787,814 to USD 4,226,836, confirming strong financial viability under both conservative and favorable conditions. Between 2028 and 2050, the Bahawalpur ISWM project is projected to achieve cumulative GHG reductions of about 1.72 million tCO_2e, translating into revenues ranging from USD 5.15 million at a conservative price of \$3/tCO_2e to nearly USD 20.6 million at \$12/tCO_2e. Annual reductions start modestly in 2028 at 10,668 tCO_2e (≈USD 32,000 at \$3) but rise sharply after 2033 when the engineered landfill gas capture system becomes fully operational, with annual credits exceeding 56,000 tCO_2e and potential revenues surpassing USD 680,000 at \$12. By 2050, reductions peak at 122,701 tCO_2e, generating between USD 368,000 and USD 1.47 million annually, depending on carbon price. This trajectory demonstrates a steadily growing and financially viable stream of climate finance, with the highest crediting benefits realized during the peak methane capture years post-2033, ensuring long-term sustainability and strong alignment with carbon market mechanisms.

4. CONCLUSION

The study concludes that implementing Integrated Solid Waste Management (ISWM) in Bahawalpur can achieve substantial climate benefits, with cumulative reductions of nearly 1.72 million tCO_2e by 2050. Key interventions such as landfill gas capture, composting, and material recovery not only mitigate emissions but also create revenue streams ranging from USD 5.15 to 20.6 million through carbon credits. These measures further deliver social and environmental co-benefits, including improved air quality, safer working conditions for informal waste workers, and enhanced resource recovery. Overall, Bahawalpur's ISWM serves as a technically feasible and financially viable model for replication across other intermediate cities in Pakistan.

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Management model with climate finance and sustainable urban development goals.

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