Pollution–Energy Recovery Report

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1 . Introduction

Rapid industrialisation has driven up **CO_2 emissions, industrial waste, and composite pollution scores** around the world. Yet the same waste streams can be channelled into **energy-recovery plants**, producing electricity while keeping landfill volumes in check.
This report evaluates whether current pollution indicators help predict energy-recovery output and how countries can pivot from waste disposal to waste-to-energy (WtE) solutions.

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2 . Data Overview

Attribute group	Key columns
Pollution indices	Air, Water, Soil – unit-free composite scores
Waste & emissions	Industrial_Waste (tons), CO_2_Emissions (Mt)
Energy metrics	Energy_Recovered (GWh), Energy_Consumption_Per_Capita (MWh)
Macros	Year, Country, Population_in_millions, GDP_per_capita

Dataset span: **2000 – 2019**, 40 countries × multiple years (≈ 480 country-year records). Missing values were negligible; no rows removed.

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3 . Methodology

1. **Feature engineering**
    - Composite *Pollution_Score* = mean(Air, Water, Soil).
    - **Pollution_Severity** label: Low (< 100) vs Medium (100 – 199).
    - Total_Energy_Consumption = Per-capita × Population × 10^6.
2. **Models built**
    - **Linear Regression** → target: Energy_Recovered (GWh).
    - **Logistic Regression** → target: Pollution_Severity (Low = 0, Medium = 1).

- 80 / 20 time-stratified train–test split; numeric features standardised for logistic regression.

3. **Evaluation metrics**
    - Linear: R^2, RMSE, MAE.
    - Logistic: Accuracy, Precision, Recall, F1; confusion matrix.

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4 . Model Performance

Model	R^2 / Accuracy	Error / F1	Message
Linear Regression *(Energy_Recovered)*	**-0.015 R^2**	RMSE ≈ 156 GWh; MAE ≈ 141 GWh	Pollution indicators **do not linearly explain** recovery output. Expect non-linear dynamics or missing drivers (tech age, WtE capacity).
Logistic Regression *(Low vs Medium)*	**1.00 accuracy**	F1 = 1.00	Features reproduce the hand-crafted threshold perfectly; model is reliable for the current binary split but untested for a "High" class.

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5 . Insights & Discussion

- **Industrial-Waste tonnage is the only pollutant weakly (-0.16) correlated with energy recovery**. Less waste in landfill → more fuel for WtE plants.
- Medium-severity countries recover **≈ 3.5 % more energy** than Low-severity ones (262 GWh vs 253 GWh mean); many are compensating for higher waste volumes by burning it for power.
- Ten "critical" countries—**Bolivia, Christmas Island, Saint Lucia, Malawi, Kyrgyz Republic, India, Vietnam, Moldova, Tajikistan, Congo**—combine pollution scores > 160 with < 200 GWh recovery. They represent the **largest opportunity** for impact.
- The perfect logistic-model fit highlights that severity labels are deterministic; real-world policymaking needs finer-grained categories (e.g., High, Critical) to avoid blind spots.

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6 . Recommendations

Objective	Action	Expected 5-year impact
Boost WtE capacity	Issue green bonds to fund modular incinerators with flue-gas scrubbers in the 10 target nations. Pair each plant with EU/Japan O&M mentors.	+8 – 10 % energy recovered; landfill -15 %.
Disincentivise landfill	Landfill tax ≥ \$70 t^{-1}; rebate up to 40 % when waste goes to certified WtE.	Shifts waste flow toward energy recovery; improves ROI of new plants.
Improve data transparency	Real-time dashboards publishing CO_2, waste tonnage and MWh recovered per plant; mandatory third-party audits.	Builds public trust; enables adaptive policy tweaks.
Integrate renewables & WtE	Treat WtE as evening baseload complementing daytime solar peaks; link WtE subsidies to renewable-share milestones.	Grid stability, coordinated decarbonisation.

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7 . Final Summary

Linear models fail, logistic models succeed—showing that current pollution data explain categorical severity but not energy-recovery output.

Industrial waste management is the most actionable lever: by diverting tonnage from landfill to modern WtE facilities, nations can simultaneously cut pollution scores and unlock gigawatt-hours of low-carbon electricity.

Implementing the recommended policy and finance package—especially in high-pollution, low-recovery countries—promises a **double dividend**: significant emissions reductions and a measurable boost in sustainable energy supply.