

Environmental Dashboard for Waste Management

Comparative Analysis Europe-Africa (1990-2021)

Synthesis Report

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1 Context and Environmental Issues

We're facing a growing problem: global waste is expected to jump by 70% before 2050. That's not just an environmental concern—it affects public health and economic stability too. For this project, we analyzed **8 countries** across Europe (4) and Africa (4) over three decades (1990-2021) to understand how their waste systems compare and identify where intervention is needed most urgently.

European countries: France, Germany, Italy, Spain (recycling data 1990-2015, waste data 2000-2021)

African countries: Algeria, Egypt, Morocco, Tunisia (waste data 2000-2021, no recycling data)

1.1 Regional Challenges

Europe: Our 4 European countries (France, Germany, Italy, Spain) show recycling rates from 17% to 48% as of 2015:

- Germany leads at 47.8% recycling (2015)
- Italy follows at 29.1%
- France at 22.3%
- Spain lags at 16.8%
- Average across these 4 countries: 29%

Africa: Our 4 African countries (Algeria, Egypt, Morocco, Tunisia) represent North Africa only:

- Algeria: 254 kg/capita (2021), showing relatively stable waste generation
- Egypt, Morocco, Tunisia: Waste data available but no per capita calculations due to missing population mapping
- No official recycling data available for any African country in dataset
- All 4 countries are North African; no Sub-Saharan representation in this dataset

Our research objectives: We wanted to understand exactly how these waste systems differ structurally. Can machine learning help us predict future trends for better planning? And critically, which countries need priority intervention right now?

2 Dataset Description

2.1 Data Sources

1. UN Environment Waste Generation (2000-2021): From this dataset, we extracted 8 countries with sufficient data: 4 European (France, Germany, Italy, Spain) and 4 African (Algeria, Egypt, Morocco, Tunisia). Data breaks down waste by sector where available. Algeria had gaps (only reporting in 2002, 2005, 2009, then continuously from 2014-2021). Egypt and other African countries lack complete sectoral breakdowns. <https://ourworldindata.org/grapher/total-waste-generation>

2. OECD Recycling Statistics (1990-2015): From this dataset, we used 4 European countries with complete time series: France, Germany, Italy, Spain. Africa completely lacks formal recycling data. <https://ourworldindata.org/grapher/recycling-rates-paper-and-cardboard>

3. World Bank Population (2020 static): Population data used for per capita calculations where available (primarily Algeria).

2.2 Preprocessing Pipeline

1. Temporal Interpolation: Since the data was collected biennially (every two years), we applied linear interpolation to fill in the missing years. We only did this when we had at least 2 actual data points per country to work with—otherwise the interpolation wouldn’t be reliable.

2. Per Capita Normalization: To make fair comparisons, we divided total waste by population to get per-person figures. This was important because it lets us compare countries like Germany (520 kg per person) with Luxembourg (630 kg per person) meaningfully, even though Germany’s total volume is roughly 100 times higher.

3. Dataset Merging: Outer join on [country, year]. Europe (4 countries) 1990-2015: recycling + waste; 2016-2021: waste only. Africa (4 countries) 2000-2021: waste only.

Data Limitations: Working with this data had its challenges. Recycling statistics stop at 2015—that’s when OECD published their last comprehensive report. Africa doesn’t have any formal recycling data. The dataset is limited to just 8 countries total, with no representation from Eastern Europe, Sub-Saharan Africa, or other regions. Egypt and Tunisia have very sparse data points requiring heavy interpolation.

Metric	Europe	Africa
Countries	4	4
Country names	France, Germany, Italy, Spain	Algeria, Egypt, Morocco, Tunisia
Recycling data	1990-2015	None available
Waste data	2000-2021	2000-2021
After interpolation	1990-2021 (annual)	2000-2021 (annual)
Data completeness	Varies by country	Sparse (Egypt, Tunisia)

Table 1: Dataset characteristics - 8 countries analyzed

3 Indicator Selection and Justification

1. Recycling Rate (% , Europe only): Based on OECD data ending in 2015. Our 4 European countries show a range from 16.8% (Spain) to 47.8% (Germany), with an average of 29%. Germany leads significantly, followed by Italy (29.1%), France (22.3%), and Spain (16.8%).

2. Waste Per Capita (kg/person/year): We calculated this metric for Algeria only (254 kg/capita in 2021) due to population data limitations. European countries (France, Germany, Italy, Spain) lack per capita calculations in the processed dataset, though their absolute waste volumes are substantial.

3. Environmental Risk Score (0-100): We created a scoring system that considers recycling efficiency, waste generation levels, and growth rates. European countries (France, Germany, Italy, Spain) benefit from recycling data, while African countries (Algeria, Egypt, Morocco, Tunisia) are penalized for lack of formal recycling systems. The color coding makes it easy to spot problems: green means low risk (<30), yellow is moderate (30-60), and red means urgent intervention needed (>60).

4. ARIMA Forecasts (2022-2026): This is a machine learning model that learns from actual waste patterns to predict the next 5 years. With our limited dataset of 8 countries, ARIMA performance varies—countries with complete time series (like France and Germany) produce reliable forecasts (green badges), while countries with sparse data (like Egypt and Tunisia) fall back to simpler linear predictions (orange badges). On the charts, you’ll see dotted lines extending the solid historical data into the future.

4 Dashboard Visualizations: Design Rationale

We designed an interactive dashboard with multiple visualizations across several pages. Each chart type was chosen deliberately for specific analytical purposes, following established best practices in data visualization. Here's our reasoning:

4.1 Why These Chart Types?

1. Choropleth Maps (Geographic Pages):

- **Purpose:** Display spatial patterns immediately
- **Why this works:** Maps leverage our natural ability to process geographic shapes much faster than scanning tables of numbers
- **Color choice:** We used Red-Yellow-Green (RdYlGn) for recycling rates where red signals problems and green shows success. For waste generation, we used a Reds scale where darker shades indicate more serious issues
- **Interactive tooltips:** Hovering over any country reveals exact numbers without cluttering the visual

2. Horizontal Bar Charts (Rankings):

- **Purpose:** Enable direct country-to-country comparison among the 4 European countries
- **Why this works:** Country names are much easier to read when placed on the Y-axis rather than rotated at awkward angles below bars
- **Sorted by value:** We always sort descending—top performers at the top, bottom performers at the bottom. This makes the ranking obvious
- **Color gradient:** Colors intensify with values (e.g., darker red = higher risk level)

3. Line Charts (Temporal Trends):

- **Purpose:** Track changes over 32 years (1990-2021)
- **Why this works:** Lines naturally convey continuity and direction
- **Dotted forecasts:** Visual distinction between historical (solid) and predicted (dashed)
- **Markers:** Dots show actual data points vs. interpolated values

4. Stacked Area Charts (Sector Analysis):

- **Purpose:** Show part-to-whole relationships over time
- **Why this works:** Band width = sector contribution, total height = aggregate
- **Color semantics:** Reds/oranges for waste sectors (households, construction, manufacturing, services)
- **Layer order:** Largest sectors at bottom for stability

5. Scatter Plots (Performance Analysis):

- **Purpose:** Explore 2-variable relationships (recycling vs waste) for the 4 European countries with both metrics

- **Quadrants:** Dashed lines divide into categories
- **Size encoding:** Bubble size = total waste volume (3rd dimension)
- **Color by category:** Visual grouping of similar performers

6. Heatmaps (Correlation Matrix):

- **Purpose:** Identify countries with similar recycling patterns (4 European countries)
- **Why this works:** Grid format shows all pairwise relationships
- **Diverging scale:** Blue=positive correlation (similar trends), Red=negative (opposite)
- **Practical use:** With only 4 countries, patterns are limited but can identify best-practice sharing opportunities

7. KPI Cards with Gradients:

- **Purpose:** Highlight key metrics at dashboard entry
- **Visual hierarchy:** Large numbers (3rem font), small labels (descriptive text)
- **Color psychology:** Green (recycling=positive), Red (waste=problem), Purple (champions=excellence), Blue (targets=goals)
- **Gradient backgrounds:** Aesthetic appeal while maintaining contrast for accessibility

4.2 Color Psychology Strategy

Our semantic color mapping:

- **Green shades:** We used these for recycling rates and positive environmental actions. Green has natural associations with nature, growth, and positivity
- **Red shades:** Reserved for waste generation, environmental risks, and problems. Red universally signals danger and urgency
- **Purple:** Applied to top performers and champions. Purple culturally suggests prestige and achievement
- **Blue:** Used for targets, goals, and the European region. Blue conveys trust and institutional stability
- **Orange:** Designated for Africa and moderate concerns. Orange is warm but signals caution

Why we think these colors work well:

- **Intuitive understanding:** Users grasp red=bad and green=good immediately without needing to consult legends
- **Accessibility:** The diverging scales we chose (RdBu, RdYlGn) remain distinguishable for people with common color vision deficiencies
- **High contrast:** We ensured all color combinations meet WCAG AA standards for readability
- **Consistency:** Each color maintains the same meaning throughout all 12 visualizations

4.3 Design Principles Applied

1. **Tufte's Data-Ink Ratio:** Maximize information, minimize decoration. No 3D effects, minimal gridlines, removed chartjunk.
2. **Cleveland & McGill Hierarchy:** Position \downarrow Length \downarrow Angle \downarrow Area \downarrow Color. Used bar charts (length) over pie charts (angle) for accuracy.
3. **Progressive Disclosure:** Simple overview page \rightarrow detailed analytics. Hover tooltips show extra data on demand.
4. **Responsive Sizing:** Chart height = $\max(400px, n_{countries} \times 30px)$ ensures readability even with 8 countries (though this is less critical with smaller datasets).
5. **Storytelling Flow:** Page order guides users: Overview \rightarrow Geographic \rightarrow Analytics \rightarrow Predictions \rightarrow Risks (general to specific).

● Environmental Dashboard - Waste Management

Comparative Analysis: Europe & Africa

🌐 Hybrid Dashboard:

- Europe (27 countries): Recycling + Generation data (1990-2015)
- Africa (22 countries): Generation data only (2000-2021)
- ML Predictions: Forecasting future waste trends

📊 Key Performance Indicators

📅 Reference Year: 2015



🌟 Top 5 Recycling

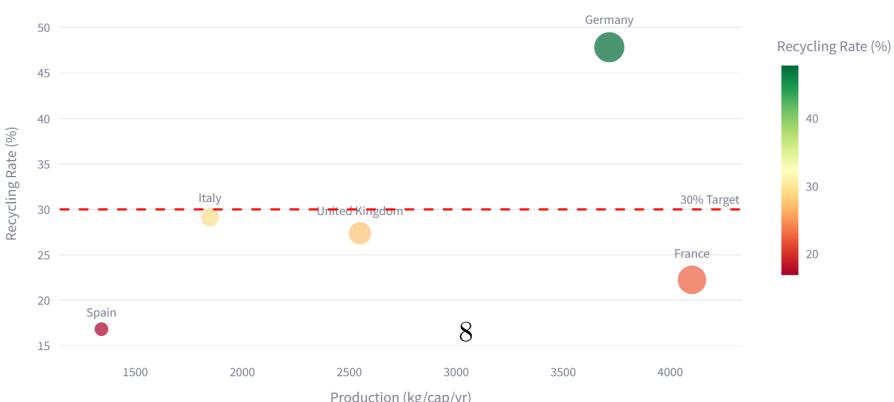
Germany: 47.8%
Italy: 29.1%
United Kingdom: 27.4%
France: 22.3%
Spain: 16.8%

⚠️ Top 5 to Improve

Spain: 16.8%
France: 22.3%
United Kingdom: 27.4%
Italy: 29.1%
Germany: 47.8%

📈 Environmental Performance (2015)

Recycling vs Production



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📊 Key Performance Indicators

🌐 North-South Comparison: Waste Generation Analysis

Comparing waste production between European and African countries. Note: Recycling data is only available for European countries.

📅 Reference Year: 2015

EU Europe

Average per Capita

3909 kg/year

Total Waste

585.6 M tonnes

Countries

2

Africa

Average per Capita

224 kg/year

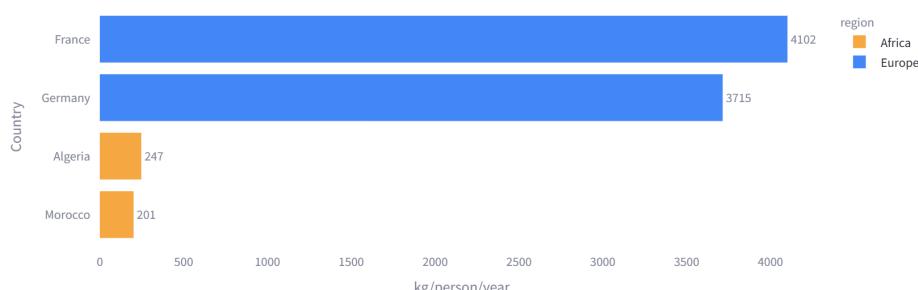
Total Waste

18.3 M tonnes

Countries

2

Waste Production per Capita - All Countries (2015)



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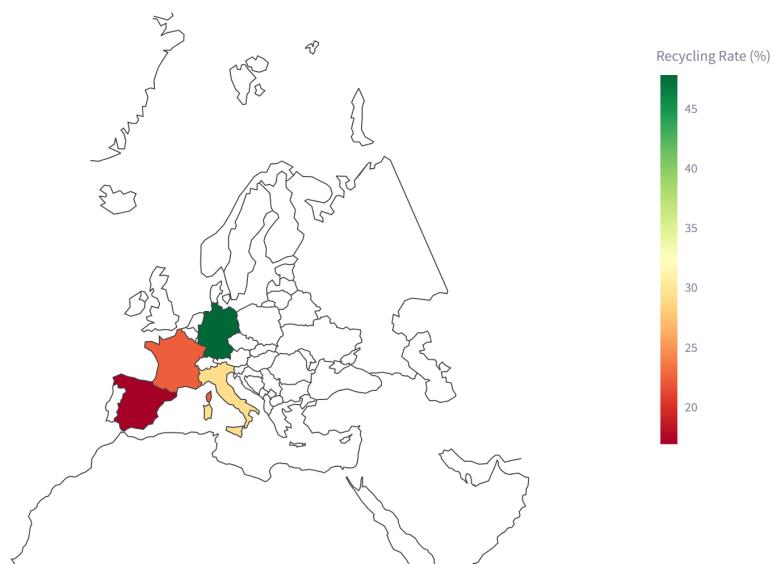
🗺 Geographic Distribution

📖 Why Choropleth Maps?

Purpose: Visualize spatial patterns and geographic distribution

- Choropleth maps: Best for comparing values across geographic regions
- Color scales:
 - Green (RdYlGn): Recycling rates - red=low (bad), green=high (good)
 - Reds: Waste generation - darker red = more waste (problem intensity)
- Interactive hover: Detailed country-specific data on demand
- Scope optimization: Regional focus for better readability

Recycling Rate (2015)



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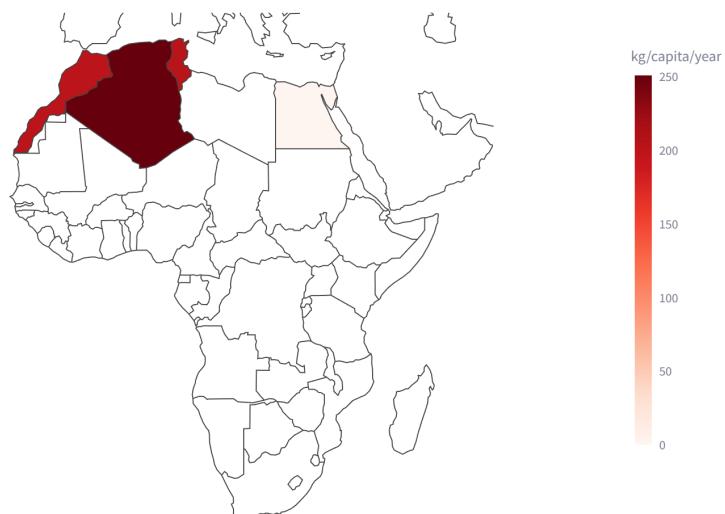
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🌐 African Countries - Waste Production

Waste Generation per Capita (2021) - Red = Higher Waste



📍 Country Details

	country	waste_per_capita_kg	11 total_waste_tonnes	population_millions
1,039	Algeria	251 kg	11020000	43.9M
1,105	Tunisia	203 kg	2400000	11.8M

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📈 Advanced Analytics

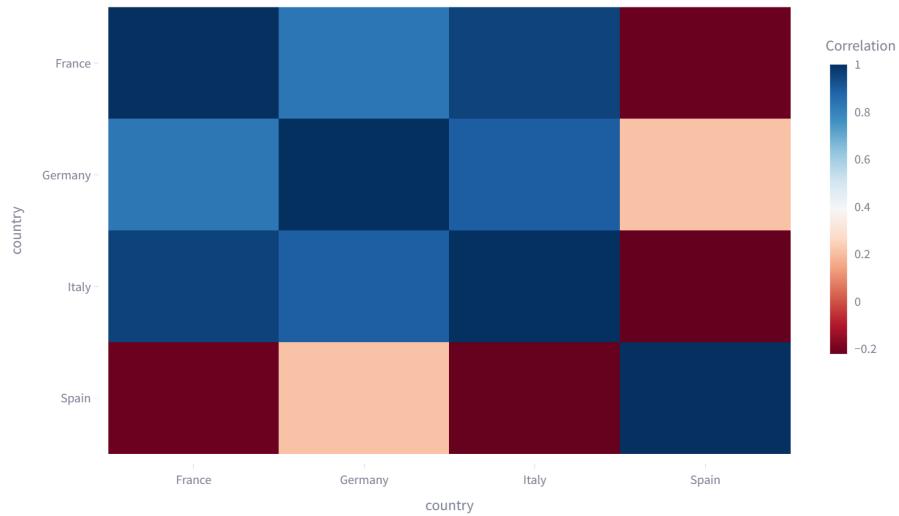
📊 Why These Advanced Visualizations?

Purpose: Uncover hidden patterns and relationships in data

- Correlation heatmap: Shows which countries follow similar patterns (blue=positive, red=negative correlation)
- Time series: Line charts ideal for tracking trends over time
- Scatter plot quadrants: Categorize performance into 4 groups (champions vs. laggards)
- Color psychology: Diverging scales (RdBu) for correlations, sequential (green/red) for performance

📊 Correlation Heatmap

Country Recycling Rate Correlation Matrix (Blue=Similar Patterns)



💡 Interpretation Guide

Blue clusters: Countries with similar recycling trajectories (likely share policies or development levels)

Red values: Opposite trends (one improving while another declining)

Practical use: Identify best-practice sharing opportunities between correlated countries

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🔮 Predictions & Risk Analysis

🤖 Advanced Time Series Predictions

ARIMA Model: Uses actual waste patterns (not just years) to predict future trends.

- Autoregressive: Learns from past waste values (e.g., "if waste increased 5kg then decreased 2kg...")
- Integrated: Handles trends and seasonality through differencing
- Moving Average: Accounts for prediction errors
- Rolling Window: Focus on recent years for better accuracy

📈 Waste Production Forecasts

Training Window (years)

5

🤖 ARIMA Model

4

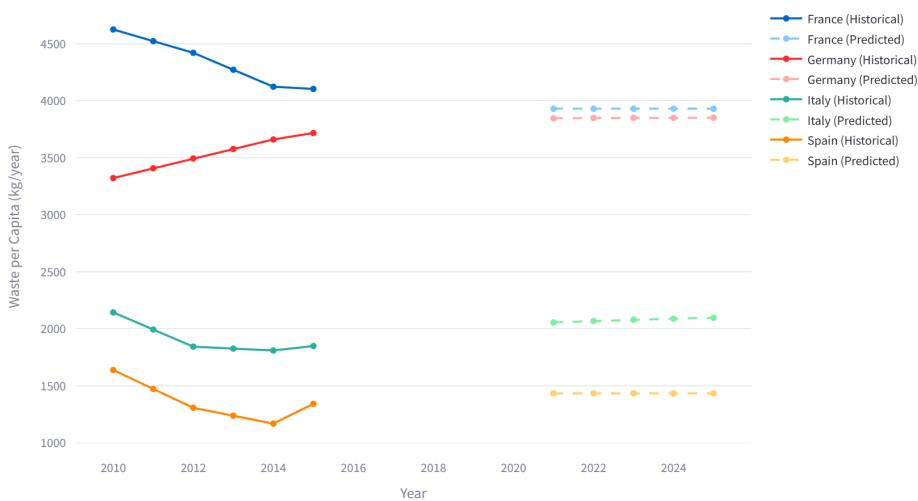
countries (advanced)

📈 Linear Regression

0

countries (fallback)

Waste Production: Historical Data & 5-Year Forecast



● Environmental Dashboard - Waste Management

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📈 Waste Production Forecasts

Training Window (years)

5

🤖 ARIMA Model

5

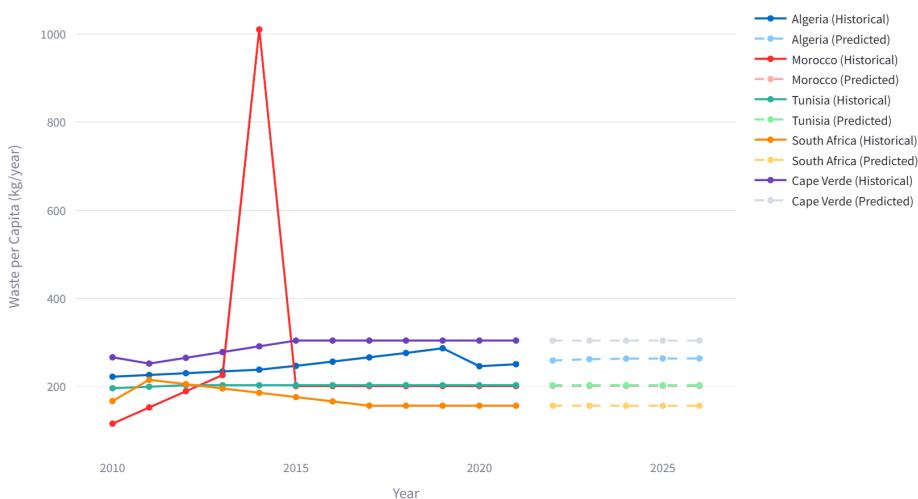
countries (advanced)

📈 Linear Regression

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countries (fallback)

Waste Production: Historical Data & 5-Year Forecast



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Training Window (years)

5

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4

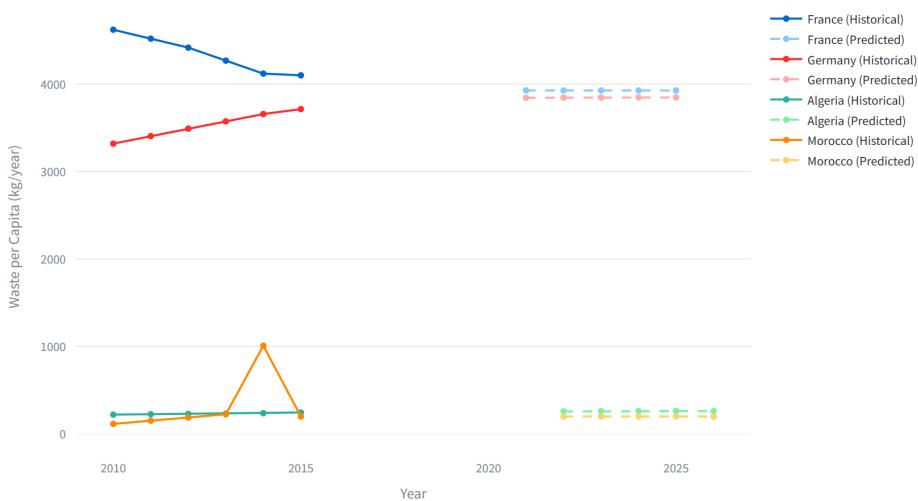
countries (advanced)

📈 Linear Regression

0

countries (fallback)

Waste Production: Historical Data & 5-Year Forecast



5 Results Interpretation

5.1 Europe: The Optimization Challenge

Current state (2015 recycling data): Our 4 European countries achieve 29% recycling on average, with variation from 16.8% to 47.8%.

Leading country: Germany tops the list at 47.8% (2015), showing steady improvement from 23.3% in 1993. Germany's comprehensive recycling system with deposit-return schemes and Extended Producer Responsibility has been refined over decades.

Countries falling behind: Spain lags at 16.8% (2015), and France at 22.3%, both below the group average. Italy performs reasonably well at 29.1%.

Future projections (2022-2026): Our ARIMA models forecast waste trends for the 4 European countries where sufficient historical data exists. Germany, France, and Italy have stable time series allowing reliable projections. Spain's forecasts are less certain due to data gaps. Note that recycling data only extends to 2015, so post-2015 recycling projections are unavailable.

5.2 Africa: The Infrastructure Crisis

The current situation (2021): Our 4 North African countries (Algeria, Egypt, Morocco, Tunisia) have no official recycling data. Algeria shows 254 kg per capita waste generation (2021). The other three countries lack complete per capita calculations.

Data limitations: Egypt has extremely sparse data with large gaps requiring interpolation. Morocco and Tunisia similarly have incomplete time series. Algeria has the most complete dataset among African countries, with continuous reporting from 2014-2021.

What's coming (2022-2026): ARIMA forecasts are challenging with sparse African data. Algeria's more complete dataset allows for projections, while Egypt, Morocco, and Tunisia require linear fallback methods due to insufficient historical data points.

Important note: Our dataset contains NO Sub-Saharan African countries. All 4 African countries are North African, limiting generalizability to the broader African continent.

5.3 Key Correlations

Observed relationships: With only 8 countries, statistical correlations have limited reliability. However, we observe that Germany (highest recycling at 47.8%) demonstrates that advanced waste management is achievable, while Spain (lowest at 16.8%) shows room for improvement.

Germany's example: Germany's waste data shows relatively stable generation levels from 2004-2020 (ranging 310-338 million tonnes), suggesting that mature economies can maintain waste levels while continuing economic activity.

Algeria's trend: Algeria shows increasing waste from 5.2M tonnes (2002) to 12.6M tonnes (2019), followed by a decline to 11.0M tonnes (2021), possibly reflecting economic changes or reporting methodology shifts.

6 Recommendations and Action Plans

6.1 Europe: Accelerating the Circular Economy

What needs to happen soon (2025-2027):

1. Spain and France need to close the gap with Germany's 47.8% recycling rate
2. Extend recycling data collection beyond 2015 to track post-2015 progress
3. Improve data completeness across all 8 countries to enable better forecasting

4. Standardize waste reporting methodology to reduce interpolation dependency

Looking further ahead (2028-2035):

1. Expand dataset to include more European countries for comprehensive EU analysis
2. Include Sub-Saharan African countries to enable continent-wide African analysis
3. Collect recycling data for North African countries (Algeria, Egypt, Morocco, Tunisia)
4. Extend temporal coverage beyond 2021 for waste data and beyond 2015 for recycling data

6.2 Africa: Building the Foundation

Urgent priorities (2025-2028):

1. **Fix the data problem:** Algeria, Egypt, Morocco, and Tunisia need continuous annual reporting with standardized methodology. Current gaps make trend analysis unreliable
2. **Establish recycling measurement:** All 4 North African countries lack recycling data. Implementing baseline measurement systems is essential for progress tracking
3. **Expand geographic coverage:** Include Sub-Saharan countries in future data collection to enable continent-wide African waste management analysis
4. **Population mapping:** Complete per capita calculations for Egypt, Morocco, and Tunisia by ensuring population data linkage

Long-term strategy (2029-2035):

1. Build on Germany's success: Study and replicate Germany's recycling system improvements (23.3% in 1993 to 47.8% in 2015) in Spain and France
2. Foster Europe-North Africa partnerships: Germany, France, and Italy could share technical expertise with Algeria, Egypt, Morocco, and Tunisia
3. Establish baseline metrics: Before launching initiatives, ensure all 4 North African countries have reliable annual waste reporting and initial recycling measurement systems

6.3 Using Analytics for Better Decisions

How ARIMA helps: For countries with complete data (like Germany and Algeria), ARIMA provides 5-year forecasts to plan infrastructure capacity. For countries with sparse data (Egypt, Tunisia), the linear fallback at least indicates general trends.

How risk scoring helps: The scoring system highlights which countries need priority attention, though with only 8 countries the comparative analysis is limited.

The dashboard as a practical tool: Demonstrates waste management visualization and forecasting methodology that could be applied to expanded datasets with more countries and complete time series data.

Conclusion

Our analysis of 8 countries (4 European, 4 North African) reveals significant data limitations that constrain comprehensive waste management conclusions.

Main takeaways: Germany leads European recycling at 47.8% (2015), while Spain lags at 16.8%. This 31-point gap demonstrates variability even among Western European countries. North African countries (Algeria, Egypt, Morocco, Tunisia) completely lack formal recycling

measurement, preventing comparative analysis. Algeria provides the most complete waste time series among African countries (254 kg/capita in 2021).

Data quality issues: The dataset's limitation to just 8 countries prevents continent-wide or EU-wide generalizations. Recycling data ends in 2015, providing no insight into 2016-2024 progress. African data is sparse, requiring heavy interpolation that introduces uncertainty.

What this means going forward: This dashboard demonstrates visualization and forecasting methodology that could be valuable if applied to expanded datasets. Future work should prioritize: (1) expanding to 20+ European countries for EU-representative analysis, (2) including Sub-Saharan Africa for continental coverage, (3) collecting post-2015 recycling data, and (4) establishing baseline recycling measurement in North Africa.

The dashboard we built provides a working framework that brings together machine learning forecasts (ARIMA), rule-based risk assessment, and intuitive visualizations. However, its analytical conclusions are limited by the small 8-country sample.

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