Sustainability and ESG Data Analytics

ESG Data Gathering, Analysis, and Visualization

1141ESGDA05
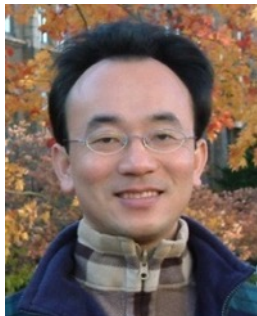MBA, IM, NTPU (M5265) (Fall 2025)
Wed 2, 3, 4 (9:10-12:00) (B3F17)

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Professor and Director

Institute of Information Management, National Taipei University

https://web.ntpu.edu.tw/~myday

https://meet.google.com/miy-fbif-max

2025-10-15

Syllabus

Week   Date   Subject/Topics

1 2025/09/10 Introduction Sustainability and ESG Data Analytics

2 2025/09/17 Environmental, Social, and Governance (ESG) in
          Net-Zero Digital Transformation

3 2025/09/24 Data Science for Sustainability and ESG

4 2025/10/01 Case Study on Sustainability and ESG Data Analytics I

5 2025/10/08 Web 3.0 and Big Data Analysis in Fintech, Green and
          Sustainable Finance

6 2025/10/15 ESG Data Gathering, Analysis, and Visualization

Syllabus

Week   Date   Subject/Topics

7 2025/10/22 NVIDIA Building RAG Agents with LLMs Part I:
LLM Services and AI Foundation Models

8 2025/10/29 Self-Learning

9 2025/11/05 Midterm Project Report

10 2025/11/12 NVIDIA Building RAG Agents with LLMs Part II:
Document Loading, Chunking, and Embeddings

11 2025/11/19 NVIDIA Building RAG Agents with LLMs Part III:
Retrieval-Augmented Generation with
Vector Stores and RAG Evaluation

Syllabus

Week   Date   Subject/Topics

12 2025/11/26 Case Study on Sustainability and ESG Data Analytics II

13 2025/12/03 Artificial Intelligence of things (AIoT) in ESG and
                    Sustainability Applications

14 2025/12/10 Generative AI for ESG Rating and Reporting Generation

15 2025/12/17 Final Project Report I

16 2025/12/24 Final Project Report II

ESG Data Gathering, Analysis, and Visualization

Outline

- **ESG Data Gathering**

- **ESG Data Analysis**

- **ESG Data Visualization**

ESG Data Challenge: Bridging the Gap

Traditional: Manual & Siloed

Spreadsheets
↓
Emails & PDFs
↓
Departmental Silos
↓
Inconsistent, Slow Reporting

AI: Automated & Centralized

API & System Integrations
↓
Centralized Data Platform
↓
AI-Powered Analytics
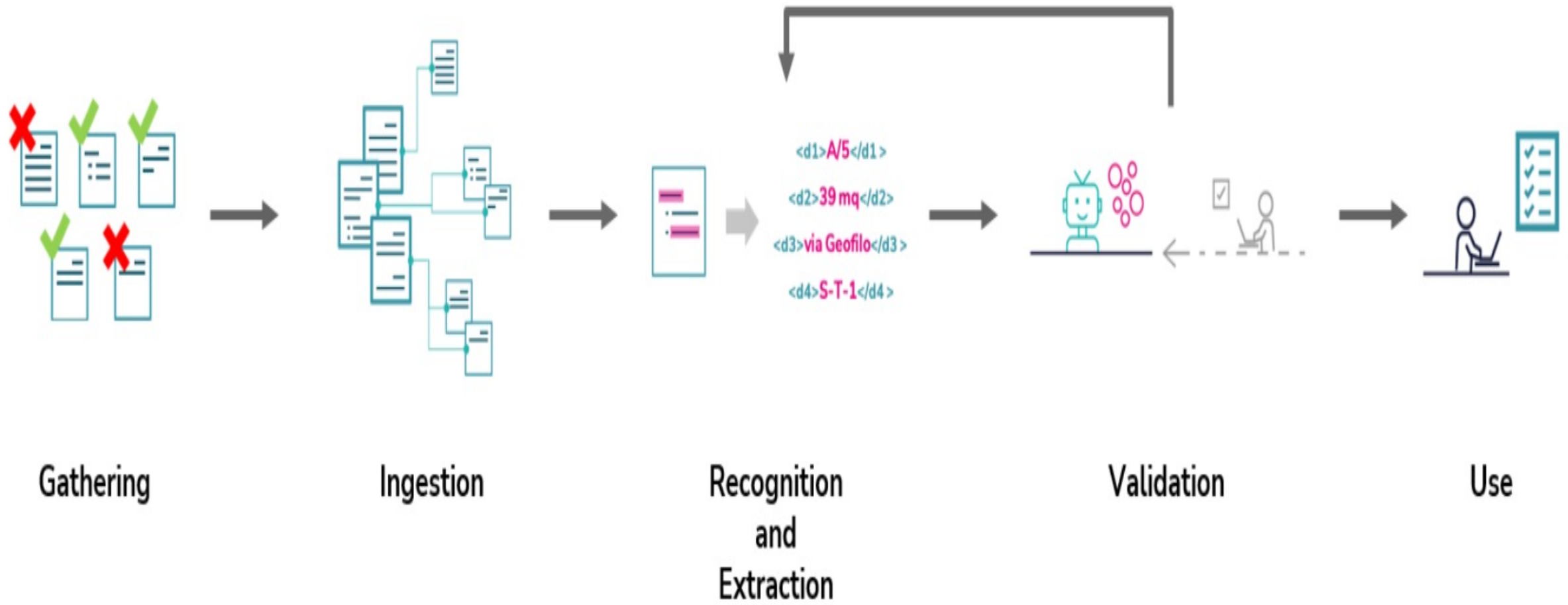↓
Auditable, Real-Time Insights

ESG Data Gathering

- **Fundamentals of ESG Data**
  - **Defining ESG**
  - **Types of ESG Data**
  - **Key ESG Data Sources**
    - ESG rating providers (MSCI, Sustainalytics, Bloomberg)
    - Corporate sustainability reports
    - Government databases
    - Non-profit and research organizations

ESG Data Gathering

- **Real-World Example**
  - **Analyzing carbon emissions data of a multinational company over time (data source: company reports, CDP)**
- **Python Integration**
  - **Python Pandas**
    - Loading and manipulating tabular ESG data
  - **Data Cleaning and Preprocessing**
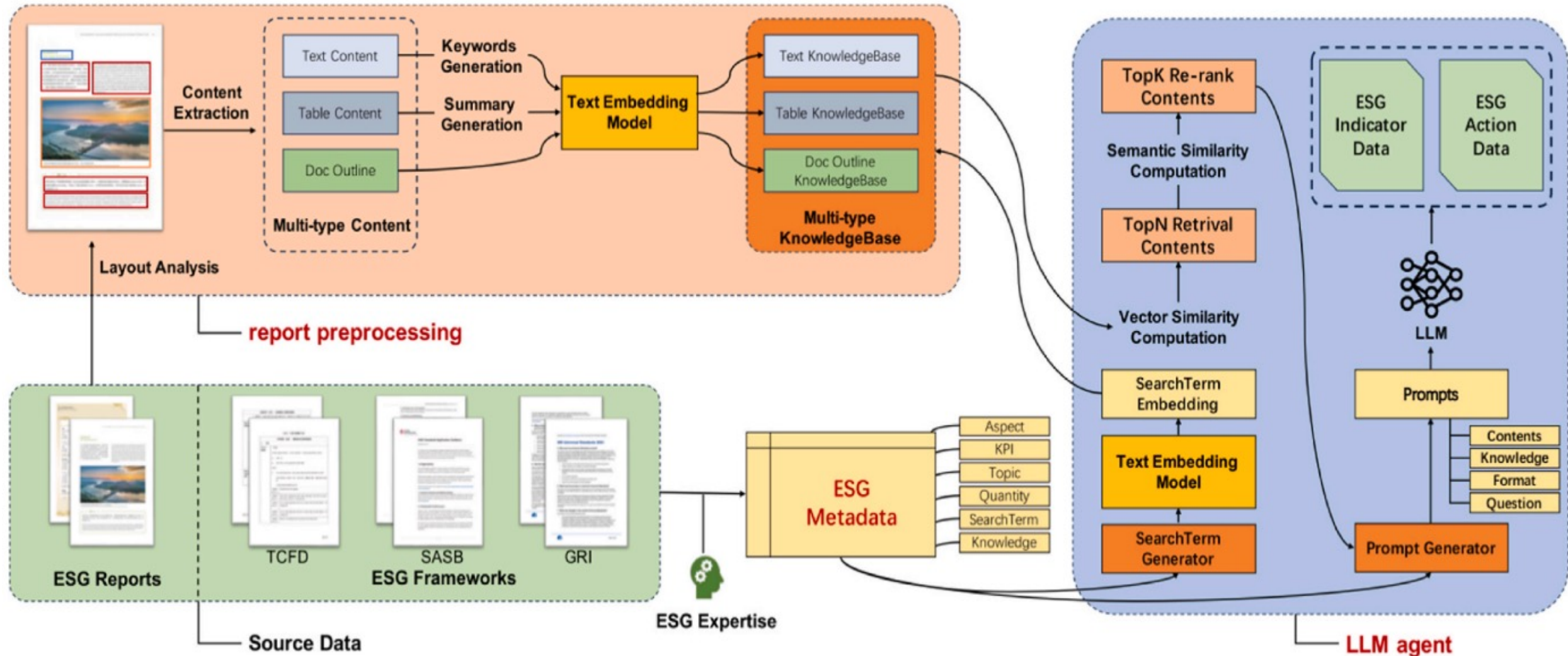   - Handling missing values, outliers, and data normalization

ESG Data Collection Process

Gathering   Ingestion   Recognition and Extraction   Validation   Use

Source: Visalli, Francesco, Antonio Patrizio, Antonio Lanza, Prospero Papaleo, Anupam Nautiyal, Mariella Pupo, Umberto Scilinguo, Ermelinda Oro, and Massimo Ruffolo. "ESG Data Collection with Adaptive AI." In ICEIS (1), pp. 468-475. 2023.

ESGReveal:

An LLM-based approach for extracting structured data from ESG reports

The three-module design (ESG Metadata module, Report Preprocessing module, and LLM Agent module)

ESGReveal ESG Metadata Module: Entities, Extensions, and Expressions

ESG Metadata = <Aspect, KPI, Topic, Quantity> + <SearchTerm, Knowledge> + Prompt Templates

Entities — Extensions — Expressions

Please use the above information, do not deviate from the given material answer:
In terms of [Aspect], extract the [KPI] of the last year with [Topic], and give [Quantity]. Return the answer in the following JSON format: {"KPI" : "<KPI>", "Topic" : "<topic>", "value" : "<value>", "Unit" : "<unit>"}

ESGReveal ESG Metadata:
An example of the main contents of one KPI

Aspect	KPI	Topic	Quantity	Search Term	Knowledge
A1. Emissions	Total waste produced (in tonnes) and, where appropriate, intensity (e.g., per unit of production volume, per facility)	[Non-hazardous Waste, Hazardous Waste]	[Absolute Values]	Construction waste, building rubbish, soil, rubble, organic waste, recyclable fertilizer, paper, plastic bottles, wood, household garbage	Hazardous waste typically includes the following categories: toxic chemical waste, electronic waste, hazardous gas waste, dangerous waste.

13

Ablation study on ESGReveal

performance of data extraction accuracy (AccDE) and
disclosure coverage accuracy (AccDC) by integrating different modules

14
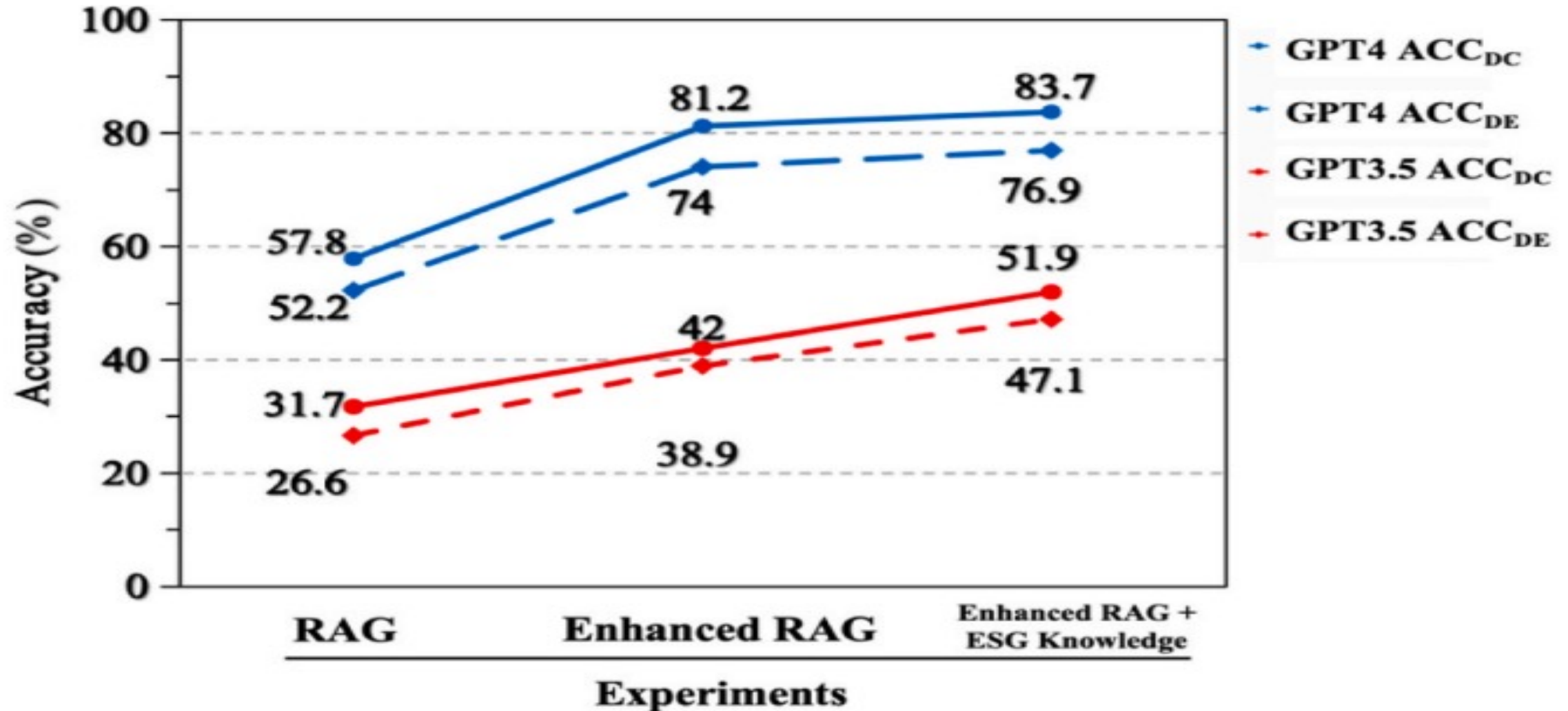
ESGReveal Disclosure levels by sector:
(a) overall,
(b) environmental issues
(c) social issues.
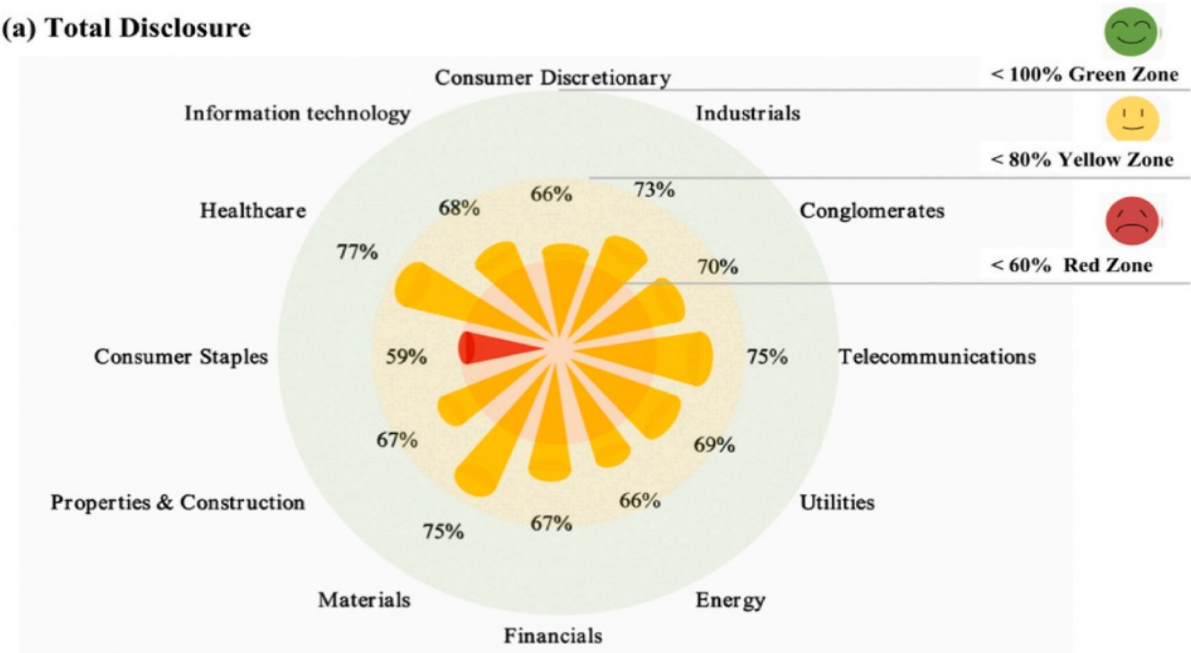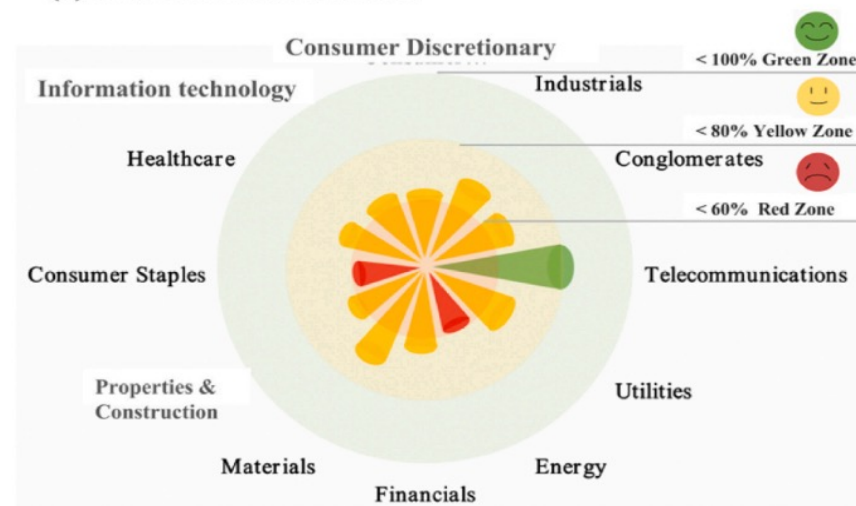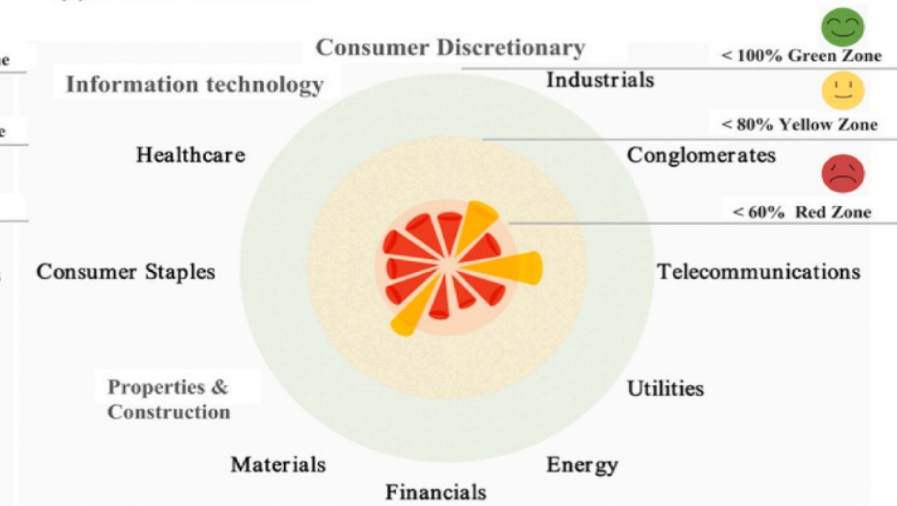
SusGen-GPT:
A Data-Centric LLM for Financial NLP and Sustainability Report Generation

Analyst-driven vs. AI-driven ESG

Analyst-driven ESG research
Derives ratings in a structured data model

Sustainalytics

Collect data → Process data → Analyze data → Generate score/rating

DATA MINERS & TECHNOLOGY | ANALYSTS

Analyst role at the end of the process allows subjectivity to color results

AI-driven ESG research
Derives signals from unstructured data

Truvalue Labs

Develop algorithms → Extract signals → Analyze data → Generate score/rating

ANALYSTS & ENGINEERS | TECHNOLOGY

Analyst expertise at the beginning of the process produces consistent results

Analyst based ESG Research

AI based ESG Research

Analyst Based ESG Research

| Collect Data | Process Data | Analyze Data | Generate score rating |

Raw data sources and tools — Analysts

Applying AI to ESG Research

| Develop algorithms | Extract signals | Analyze data and uncover material impact | Review and determine investment decision |

Analysts and Engineers — Technology — Analysts
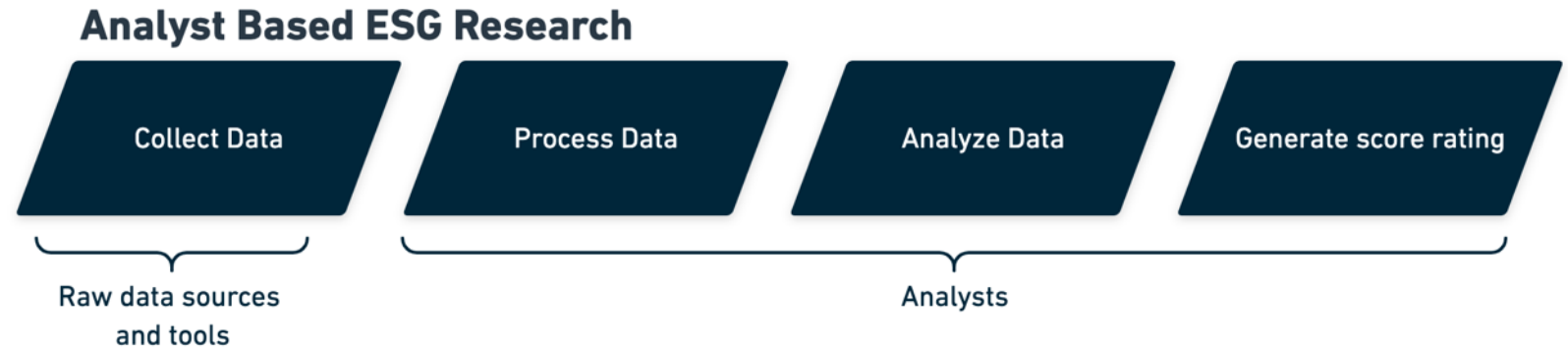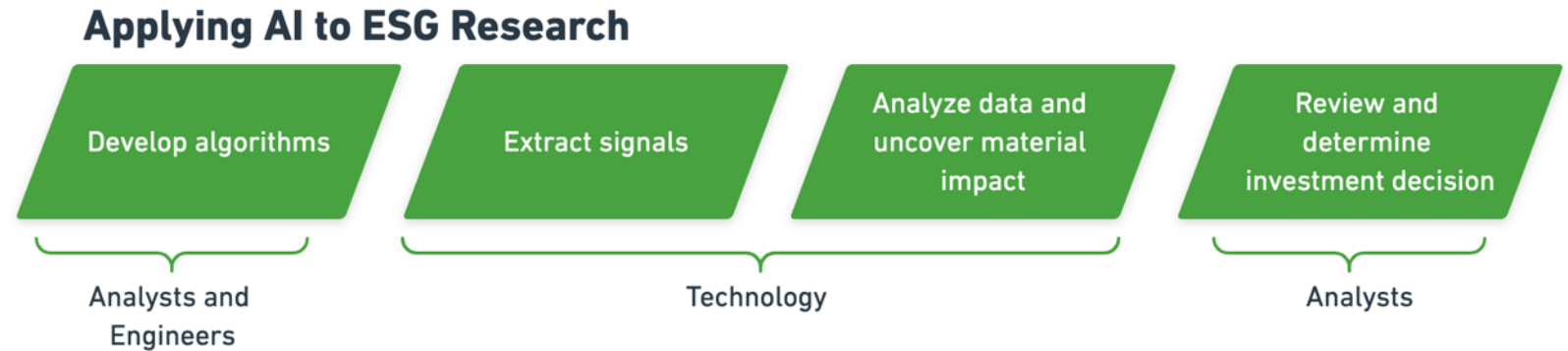
It would take an analyst over 5 years to do what our AI can in 1 week
Combining analysts with AI creates gives you the full picture

+ AI =
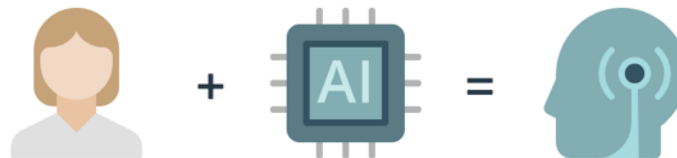
ESG ANALYTICS
Invest where it matters.

ESG Data Analysis

- **ESG Metrics and Frameworks**
  - **Popular frameworks (GRI, SASB, TCFD)**
  - **Calculating key ESG ratios**
    - (e.g., debt-to-equity,
      employee turnover rate,
      energy efficiency metrics)
- **Statistical Analysis of ESG Data**
- **Time Series Analysis**

ESG Data Analysis

- **Real-World Example**
  - **Examining the correlation between gender diversity on corporate boards and profitability**
    - (data source: Bloomberg, MSCI)
- **Python Integration**
  - **Statistical Libraries**
    - Using SciPy and NumPy for calculations
  - **Time Series Analysis**
    - Utilizing Pandas for date/time manipulation and analysis

Python Ecosystem for Data Science

Few (~10) main libraries

GitHub
Share code

stackoverflow
Information

Machine Learning

Statistics

pandas
$y_{it} = \beta' x_{it} + \mu_i + e_{it}$
Structured data

SciPy
Scientific

matplotlib
Graphics

jupyter
Lab book

ANACONDA

NumPy
Numerical data (arrays)

python
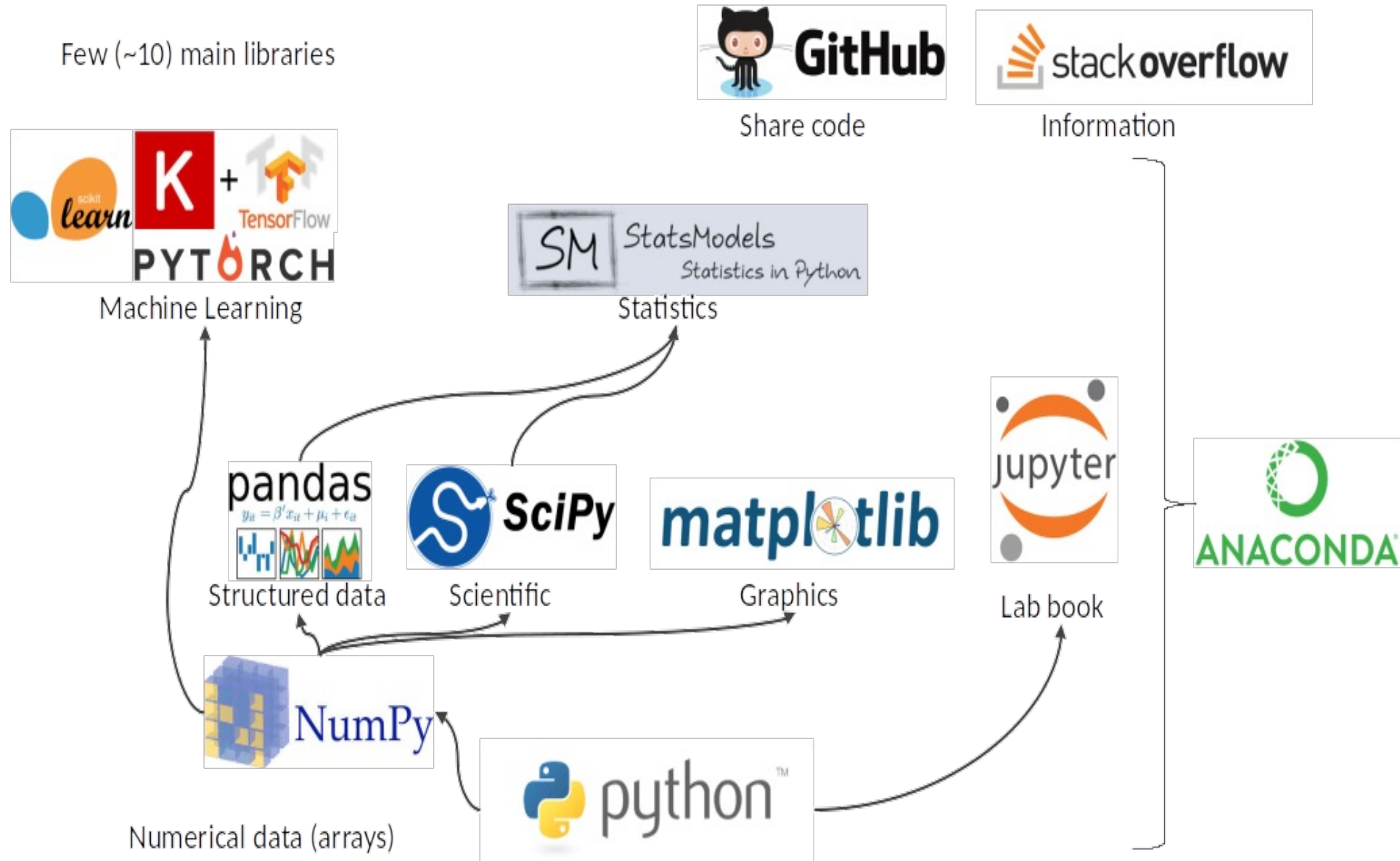
ESG Analytics: NLP Taxonomy
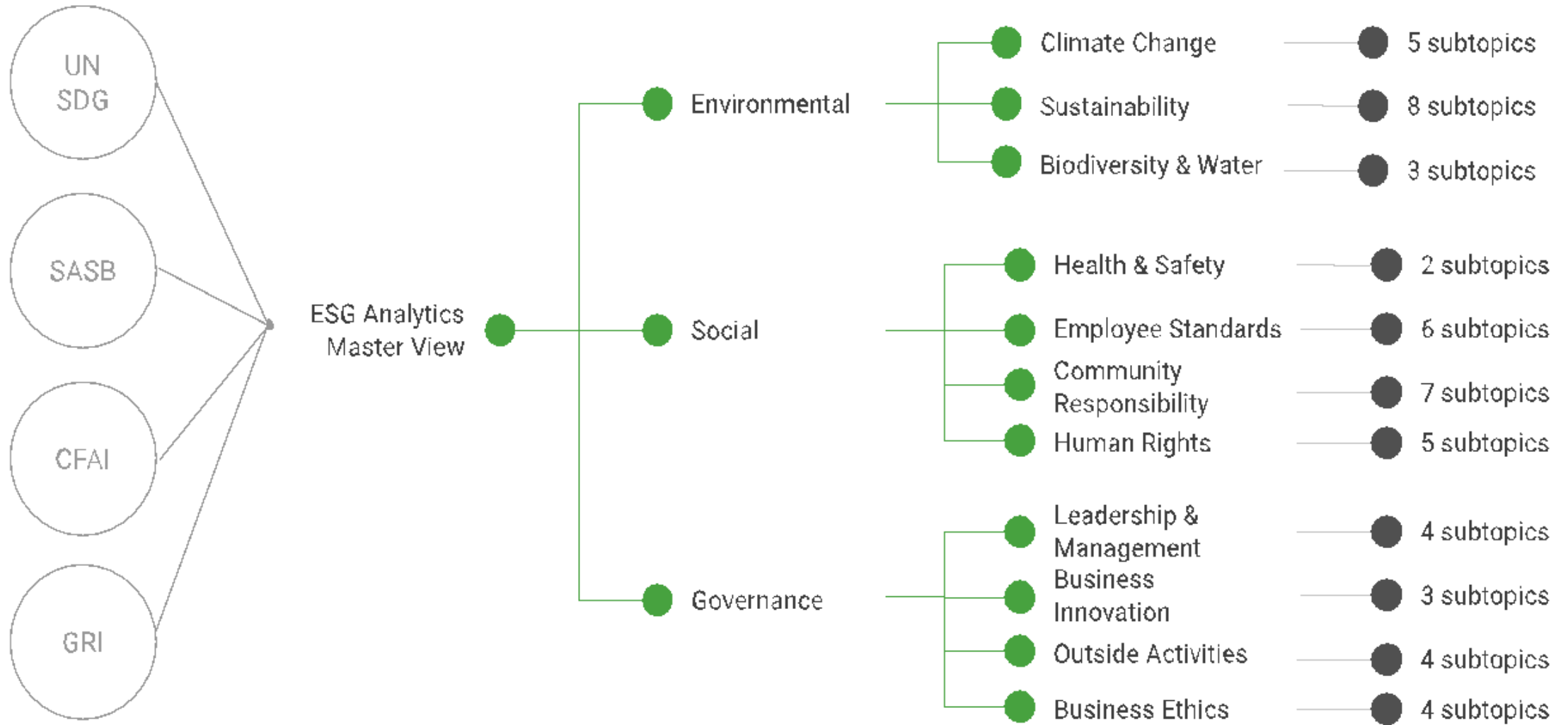
ESG Data Visualization

- **Principles of Effective Data Visualization**

- **ESG Dashboards**

- **Interactive Visualizations**

- **Real-World Example: Visualizing a company's ESG performance against industry benchmarks using a dashboard.**

ESG Data Visualization

- **Real-World Example**
  - **Visualizing a company's ESG performance against industry benchmarks using a dashboard.**
- **Python Integration**
  - **Visualization Libraries**
    - Matplotlib, Seaborn, or Plotly
  - **Dashboarding Tools**
    - Streamlit or Dash for creating simple interactive dashboards

Fundamentals of ESG Data

- **ESG Data Gathering, Analysis, and Visualization: Practical Techniques and Python Applications**
- **What ESG data is**
  - **where to find it**
  - **its importance in the world of sustainability**

Environmental, Social, and Governance (ESG)

- **It's a framework used to evaluate the sustainability and ethical impact of companies and investments.**

- **Environmental**
  - company's interaction with the natural world.

- **Social**
  - company's relationships with people – its workers, customers, and communities.

- **Governance**
  - how a company is led and managed.

Defining ESG

- **E – Environmental**
  - **carbon emissions, pollution, resource use, biodiversity impact.**
- **S – Social**
  - **Labor practices, human rights, diversity & inclusion, community impact.**
- **G – Governance**
  - **Board structure, executive compensation, ethics, transparency, anti-corruption.**

Importance of ESG

- **Growing investor demand**
  - **Investors are increasingly looking for companies aligned with their values on sustainability.**

- **Risk mitigation**
  - **Strong ESG performance can help companies avoid potential scandals and reputational damage.**

- **Long-term value creation**
  - **ESG factors are linked to better resource management, innovation, and improved financial performance over time.**

Types of ESG Data

- **Qualitative**
  - **Narrative information, such as policies, statements, news articles**
- **Quantitative**
  - **Numerical data, like emissions figures, employee demographics, board compensation**
- **Structured**
  - **Data that fits neatly into tables and databases**
- **Unstructured**
  - **Data like news articles, social media posts, or company reports that need further processing**

Key ESG Data Sources

- **ESG Rating Providers**
  - **Companies specializing in ESG assessments and data**
- **Corporate Sustainability Reports**
  - **Company-issued reports on their ESG activities**
- **Government Databases**
  - **Public data on environmental metrics, labor statistics, etc.**
- **Non-profit & Research Orgs**
  - **Issue-specific data on topics like human rights or climate change**

MSCI ESG Rating Framework

DATA
1,000+ data points on ESG policies, programs, and performance; Data on 100,000 individual directors; up to 20 years of shareholder meeting results

EXPOSURE METRICS
How exposed is the company to each material issue?
Based on over 80 business and geographic segment metrics

MANAGEMENT METRICS
How is the company managing each material issue?
150 policy/program metrics, 20 performance metrics; 100+ Governance Key Metrics

KEY ISSUE SCORES & WEIGHTS
35 Key Issues selected annually for each industry and weighted based on MSCI's materiality mapping framework.

ESG RATING (AAA-CCC)
Issue scores and weights combine to overall ESG rating relative to industry peers. Individual E, S, G scores also available

SOURCES
100+ specialized datasets (government, NGO, models)
Company disclosure (10-K, sustainability report, proxy report)
3,400+ media sources monitored daily (global and local news sources, governments, NGOs)

MONITORING & QUALITY REVIEW
Systematic, ongoing daily monitoring of controversies and governance events
In-depth quality review processes at all stages of rating, including formal committee review

INSIGHT
Specialized ESG research team provides additional insight through:
Company reports
Industry reports
Thematic reports
Analyst calls & webinars

DATA OUTPUTS
Access to selected underlying data
Ratings, scores, and weights on 680,000 securities
17 years of history

MSCI ESG Key Issue Hierarchy

3 Pillars	10 Themes	35 ESG Key Issues	
Environment	**Climate Change**	Carbon Emissions	Financing Environmental Impact
		Product Carbon Footprint	Climate Change Vulnerability
	Natural Capital	Water Stress	Raw Material Sourcing
		Biodiversity & Land Use	
	Pollution & Waste	Toxic Emissions & Waste	Electronic Waste
		Packaging Material & Waste	
	Environmental Opportunities	Opportunities in Clean Tech	Opportunities in Renewable Energy
		Opportunities in Green Building	
Social	**Human Capital**	Labor Management	Human Capital Development
		Health & Safety	Supply Chain Labor Standards
	Product Liability	Product Safety & Quality	Privacy & Data Security
		Chemical Safety	Responsible Investment
		Consumer Financial Protection	Health & Demographic Risk
	Stakeholder Opposition	Controversial Sourcing	
		Community Relations	
	Social Opportunities	Access to Communications	Access to Health Care
		Access to Finance	Opportunities in Nutrition & Health
Governance	**Corporate Governance**	Ownership & Control	Pay
		Board	Accounting
	Corporate Behavior	Business Ethics	
		Tax Transparency	

MSCI Governance Model Structure
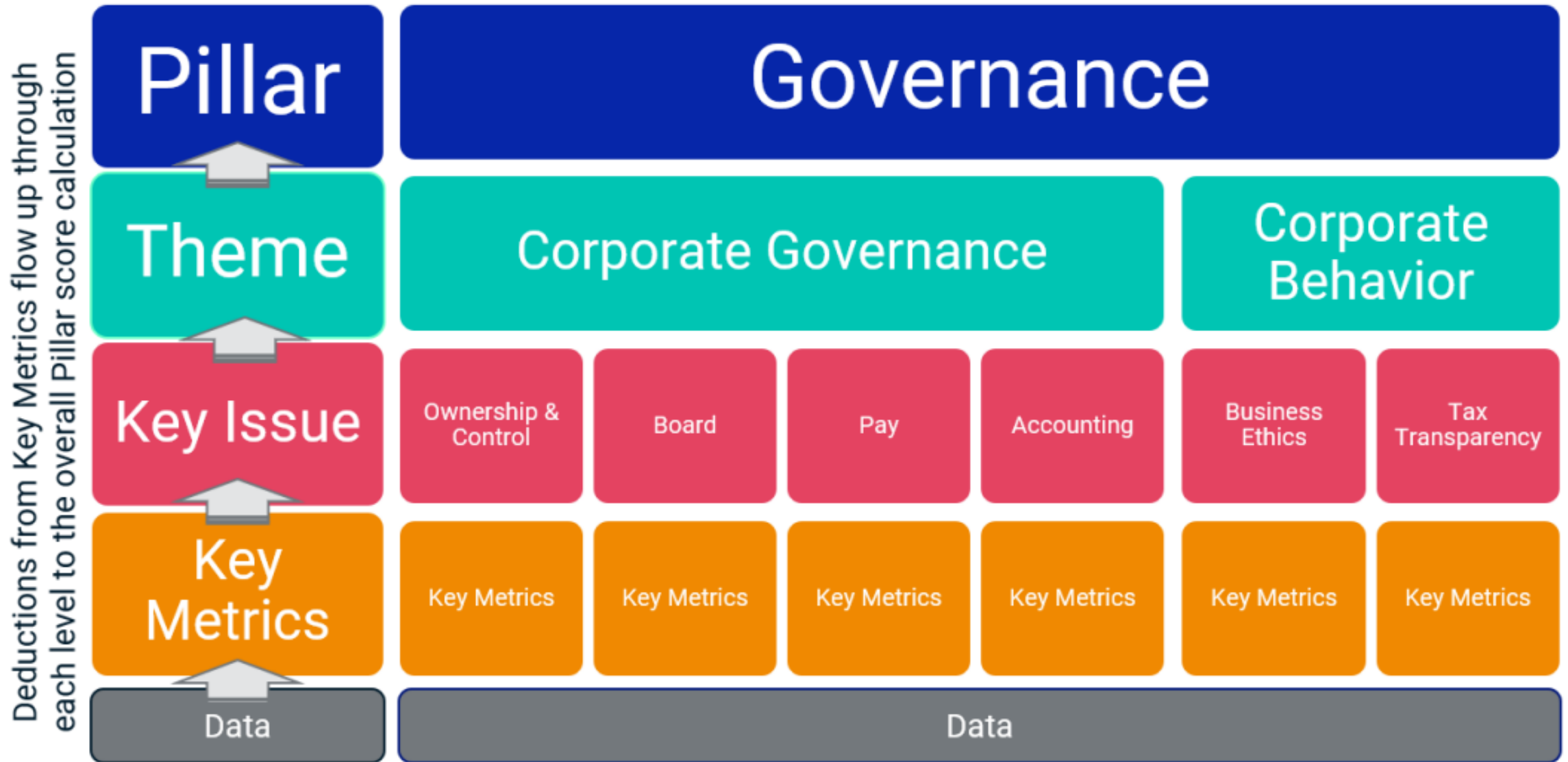
MSCI Hierarchy of ESG Scores
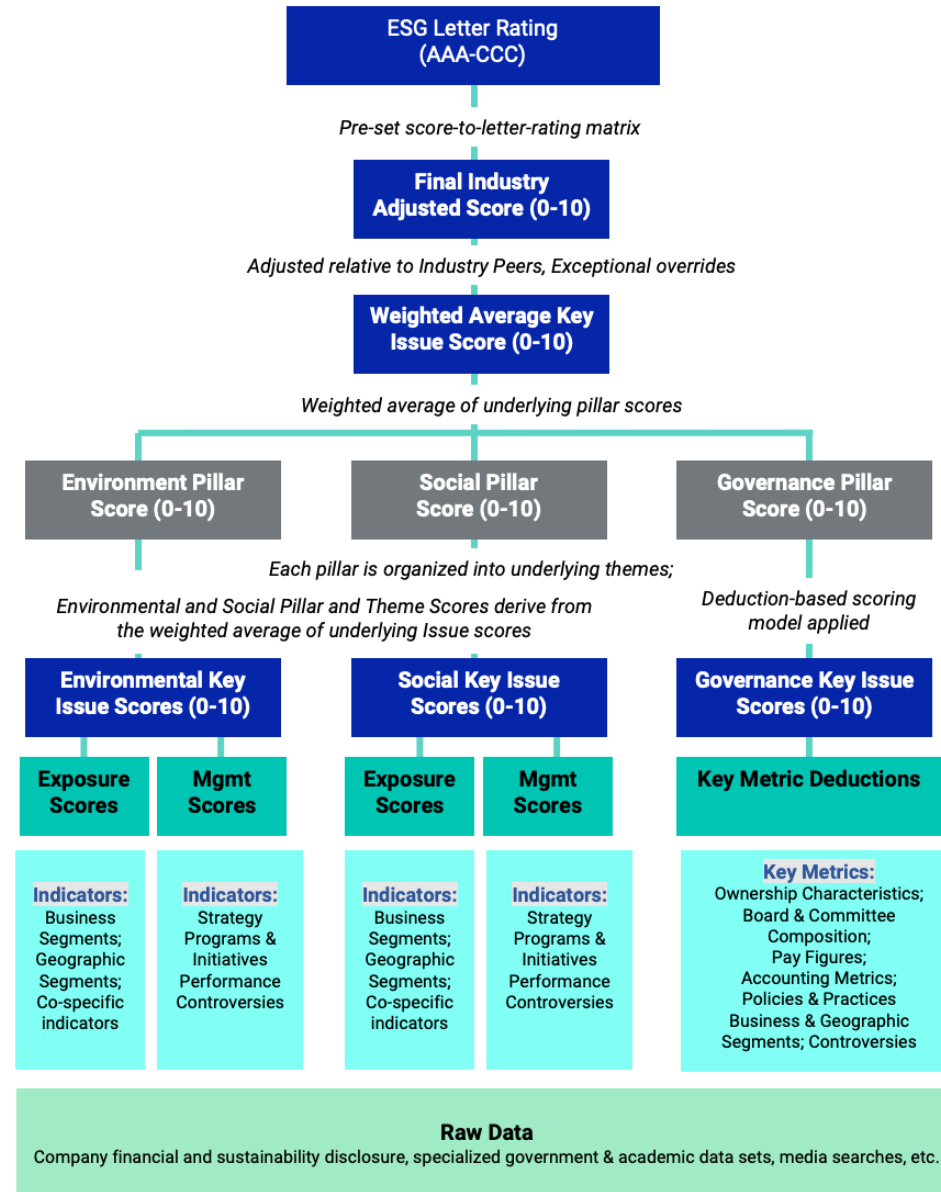
DJSI S&P Global ESG Score

8,000 Companies

90% Global market capitalization

340,000+ Current Research Universe and Active Securities
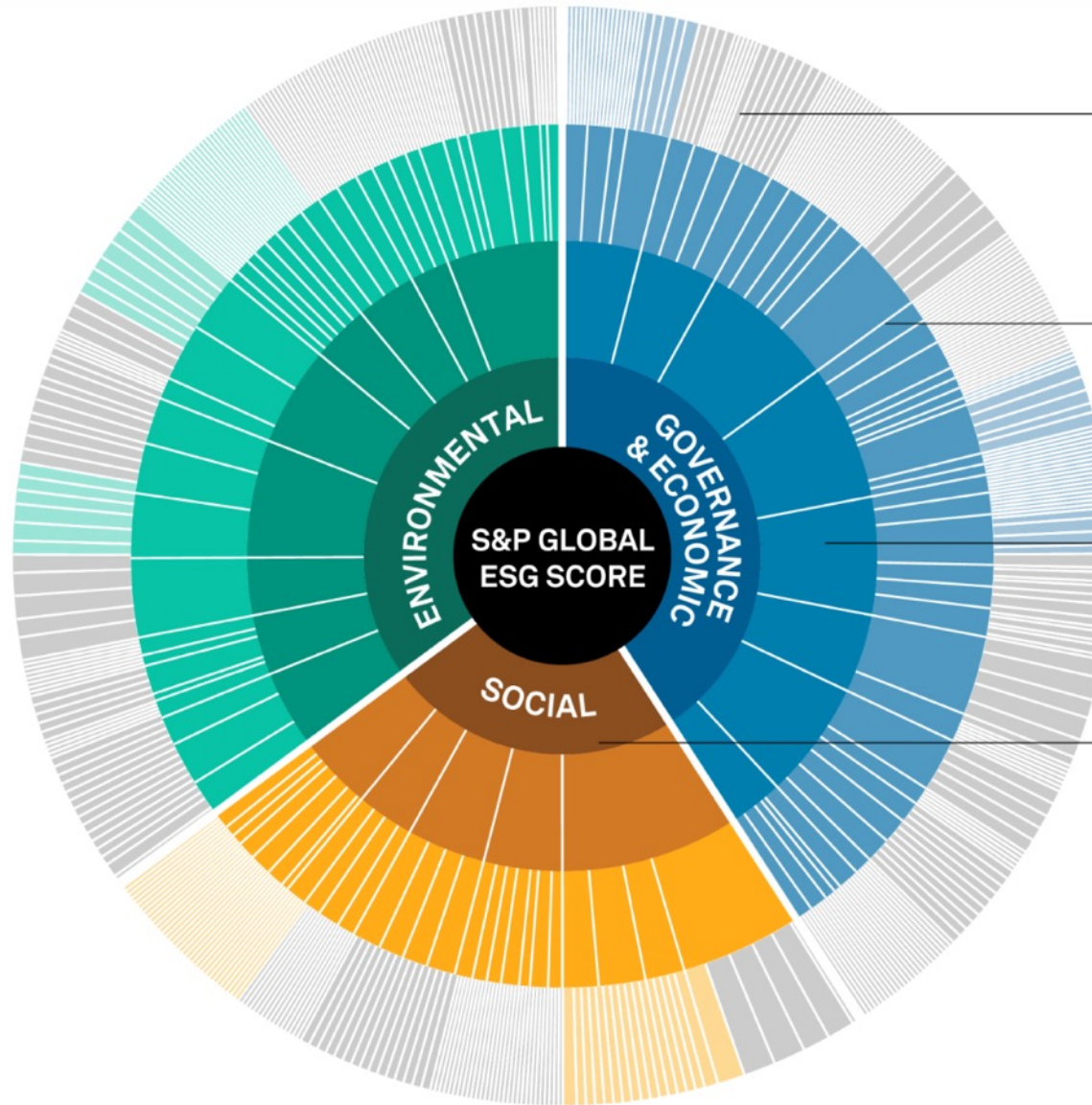
Approx. **1,000** Datapoints — Assessed values, text, checkboxes, documents
Sources: Web-based questionnaire and company documents

130+ Questions — Weighted data point scores
Up to 50% industry-specific

Ave. **30+** Criteria scores — Weighted question scores
61 industry specific approaches, with tailored questions, criteria and related weightings

3 Dimension scores — Weighted criteria scores
Adjusted for corporate ESG controversies where applicable

1 S&P Global ESG Score — Sum of weighted dimension scores

ENVIRONMENTAL · GOVERNANCE & ECONOMIC · SOCIAL

S&P GLOBAL ESG SCORE

FTSE Russell ESG Ratings

ESG Data Analysis

- **ESG Metrics and Frameworks**
- **Key ESG Ratios**
- **Statistical Analysis of ESG Data**
- **Time Series Analysis**

ESG Metrics and Frameworks

- **Metrics:**
  - **Specific ESG measures
    (e.g., carbon intensity, employee satisfaction, percentage of independent directors).**

- **Frameworks:**
  - **Standards for reporting and interpreting ESG data
    (GRI, SASB, TCFD).**

Key ESG Ratios
Financial Ratios with an ESG Twist

- **Debt-to-equity**
  - **Indicates financial risk, but also potential social or environmental liabilities.**

- **Employee turnover rate**
  - **Measure of employee satisfaction and human capital management.**

- **Energy efficiency metrics**
  - **Energy use per unit of output (shows resource optimization)**

Statistical Analysis of ESG Data
Numbers Tell a Story

- **Descriptive statistics**
  - **Summarize data (mean, median, standard deviation)**
- **Correlation**
  - **Measures the association between two ESG variables**
- **Regression**
  - **Models the relationship between ESG factors and financial performance**

Time Series Analysis
The Power of Tracking Over Time

- **Detecting trends**
  - **Are a company's emissions decreasing?**
  - **Is board diversity improving?**
- **Identifying patterns**
  - **Understanding seasonal or cyclical fluctuations in ESG data.**

Real-World Example
Gender Diversity and Profitability: A Correlation?

- **Data Source:**
  - **Bloomberg, MSCI**

- **Metrics:**
  - **Percentage of women on boards,**
  - **Return on Equity (or similar profitability metric)**

Python: Your ESG Analysis Toolbox

- **SciPy & NumPy**
  - **Powerful libraries for calculations and statistical analysis**
- **Pandas**
  - **Ideal for working with time series data and tabular ESG data**

Python Ecosystem for Data Science
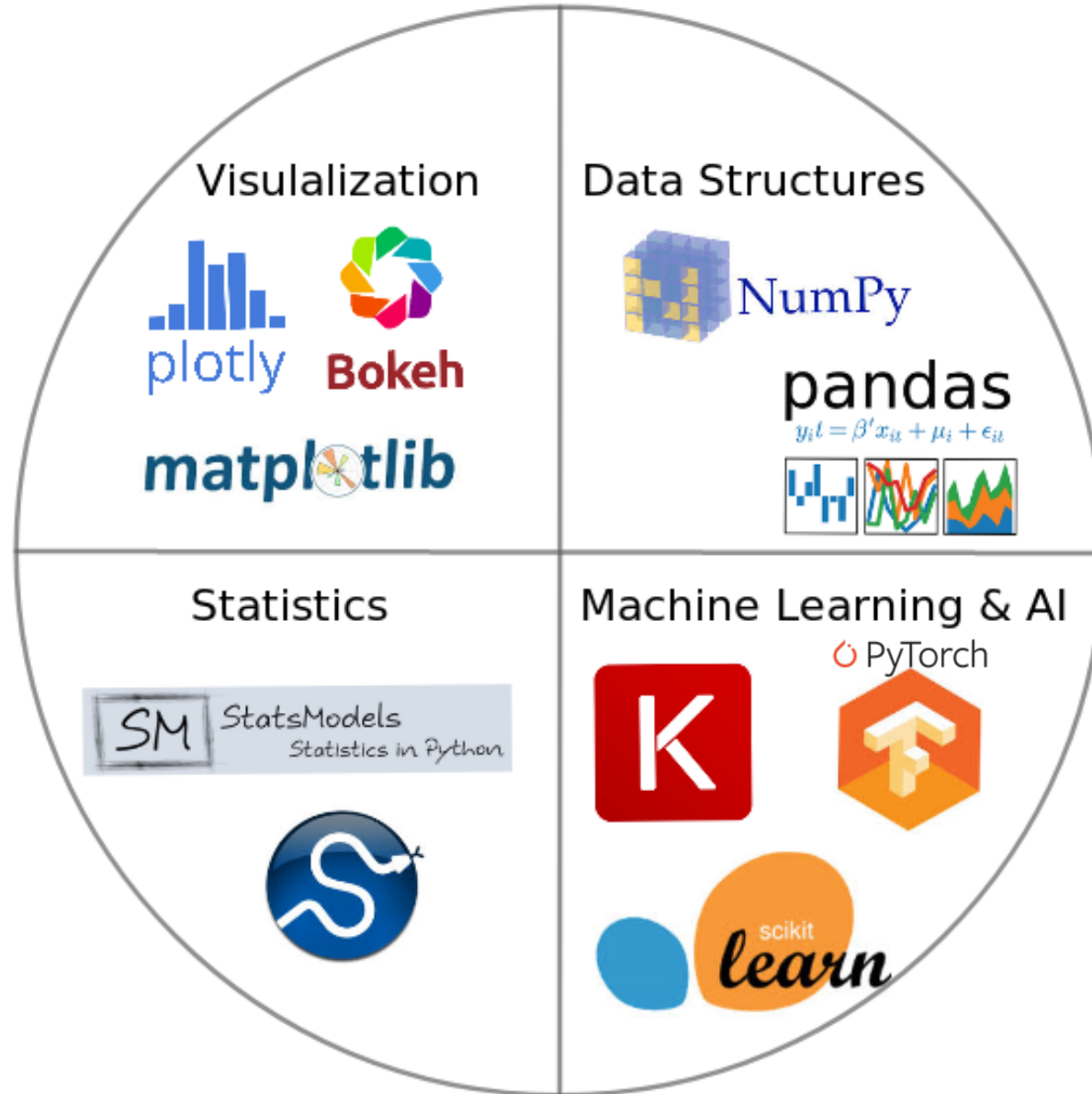
ESG Data Visualization

- **Principles of Effective Data Visualization**
- **Chart Types for ESG**
- **Storytelling with Data**
- **ESG Dashboards**

Data Analytics and Visualization with Python

Data Analytics and Visualization with Python

- **NumPy**
  - **Numerical Python N-dimensional array**
- **Pandas**
  - **Data Analytics**
- **Matplotlib**
  - **Basic Data Visualization**
- **Seaborn**
  - **Advanced Visualization**

Python Data Analysis and Visualization

Principles of Effective Data Visualization
Visualizing ESG: Clarity and Impact

- **Clarity**
  - **Choose chart types that clearly communicate the message**
- **Simplicity**
  - **Avoid visual clutter, highlight key takeaways**
- **Aesthetics**
  - **Use color and design purposefully**

Chart Types for ESG

- **Bar Charts**
  - **Comparing values across categories (emissions of different companies)**
- **Line Charts**
  - **Showing change over time (a company's energy use over years)**
- **Scatter Plots**
  - **Examining correlations (diversity vs. employee satisfaction)**
- **Pie Charts**
  - **Part-to-whole relationships (breakdown of waste types)**

Storytelling with Data
More Than Just Numbers

- **Narrative**
  - **Frame your visualizations with context and key takeaways**
- **Annotations**
  - **Use text labels and callouts directly on charts to highlight insights**
- **Visual Hierarchy**
  - **Guide the viewer's eye to the most important information**

ESG Dashboards
Your ESG Mission Control

- **Key Metrics**
  - **Track the most important indicators in one place**

- **Comparisons**
  - **Visualize performance against targets and benchmarks**

- **Interactivity**
  - **Allow users to filter data by time, company, or metric**

ESG Data Visualization
Company vs. Industry
An ESG Dashboard

Python: Your Visualization Powerhouse

- **Matplotlib & Seaborn**
  - **Foundational libraries for static plots**
- **Plotly**
  - **For highly interactive visualizations**
- **Streamlit or Dash**
  - **Tools for creating dashboard web applications**

ESG Data Analysis and Visualization

```python
# ESG Data Analysis and Visualization
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from datetime import datetime
import random

# Generate synthetic data
np.random.seed(0)
data = {
    'company': ['Company A', 'Company B', 'Company C', 'Company D', 'Company E'],
    'emissions': np.random.randint(10000, 50000, 5),
    'diversity': np.random.uniform(0.2, 0.9, 5),
    'employee_satisfaction': np.random.uniform(60, 90, 5),
    'waste_type': ['Plastic', 'Organic', 'Electronic', 'Metal', 'Other'],
    'waste_amount': np.random.randint(100, 500, 5)
}
df = pd.DataFrame(data)
```

ESG Data Analysis and Visualization

```python
# Separate DataFrame for time series and correlation
time_series_data = pd.DataFrame({
    'year': np.repeat(np.arange(2018, 2023), 5),
    'company': np.tile(['Company A', 'Company B', 'Company C', 'Company
    D', 'Company E'], 5),
    'energy_use': np.random.randint(1000, 5000, 25)
})

# Simulating correlation data with a slight positive trend
diversity = np.linspace(0.2, 0.9, 100)
np.random.shuffle(diversity)
employee_satisfaction = 60 + (diversity - 0.2) * 150
employee_satisfaction += np.random.normal(0, 5, 100)

correlation_data = pd.DataFrame({
    'diversity': diversity,
    'employee_satisfaction': employee_satisfaction
})
```

ESG Data Analysis and Visualization

```python
# Save DataFrame to CSV
df.to_csv('ESG_Dataset.csv', index=False)

# Calculate statistics for each company
statistics = df.describe()
statistics = statistics.applymap(lambda x: format(x, '.4f'))
print(statistics)
statistics.to_csv('Company_ESG_Statistics.csv')
```

	emissions	diversity	employee_satisfaction	waste_amount
count	5.0000	5.0000	5.0000	5.0000
mean	31447.6000	0.4085	77.1504	345.6000
std	11667.5748	0.1099	7.0841	94.8093
min	12732.0000	0.2397	70.1219	215.0000
25%	30757.0000	0.3909	71.7835	297.0000
50%	31243.0000	0.4083	74.3993	343.0000
75%	40403.0000	0.4691	84.3651	435.0000
max	42103.0000	0.5344	85.0824	438.0000

ESG Data Analysis and Visualization

```python
# Create visualizations and save them at 300 dpi
# Bar Chart for Emissions
plt.figure(figsize=(8, 4))
plt.bar(df['company'], df['emissions'], color='skyblue')
plt.xlabel('Company')
plt.ylabel('Emissions (Tonnes)')
plt.title('ESG Comparison of Company Emissions')
plt.show()
plt.savefig('ESG Company_Emissions.jpg', format='jpg', dpi=300)
```
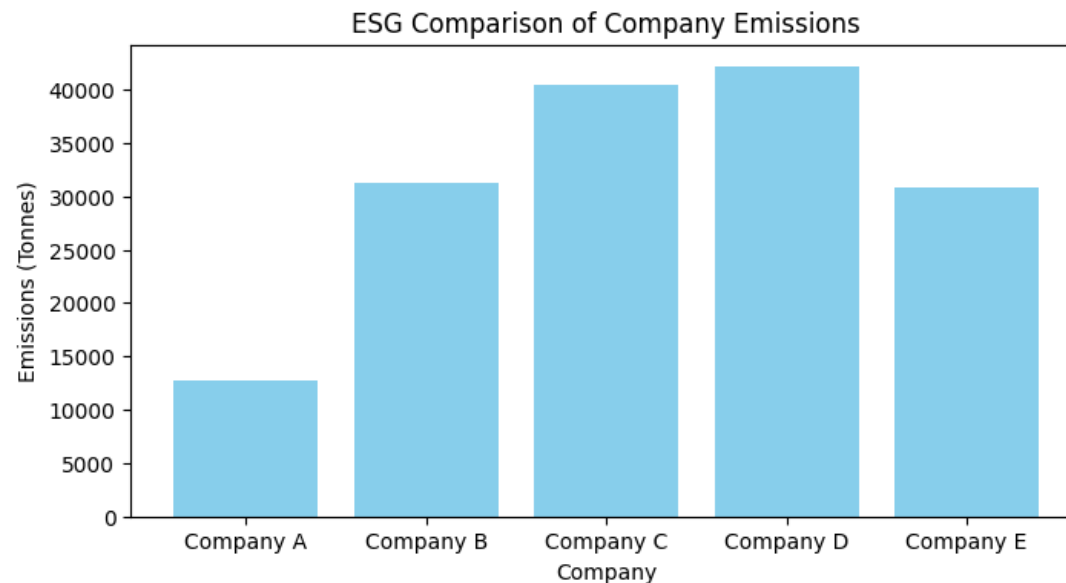
ESG Data Analysis and Visualization

```python
# Line Chart for Energy Use
plt.figure(figsize=(8, 4))
for company in time_series_data['company'].unique():
    company_data = time_series_data[time_series_data['company'] ==
    company]
    company_data = company_data.sort_values(by='year')
    plt.plot(company_data['year'], company_data['energy_use'],
    marker='o', linestyle='-', label=company)
plt.xlabel('Year')
plt.ylabel('Energy Use (kWh)')
plt.title("ESG Companies' Energy Use Over Time")
plt.xticks(company_data['year'].unique()) # Ensuring only whole years
are marked
plt.legend()
plt.grid(True)
plt.show()
```

ESG Data Analysis and Visualization

ESG Companies' Energy Use Over Time
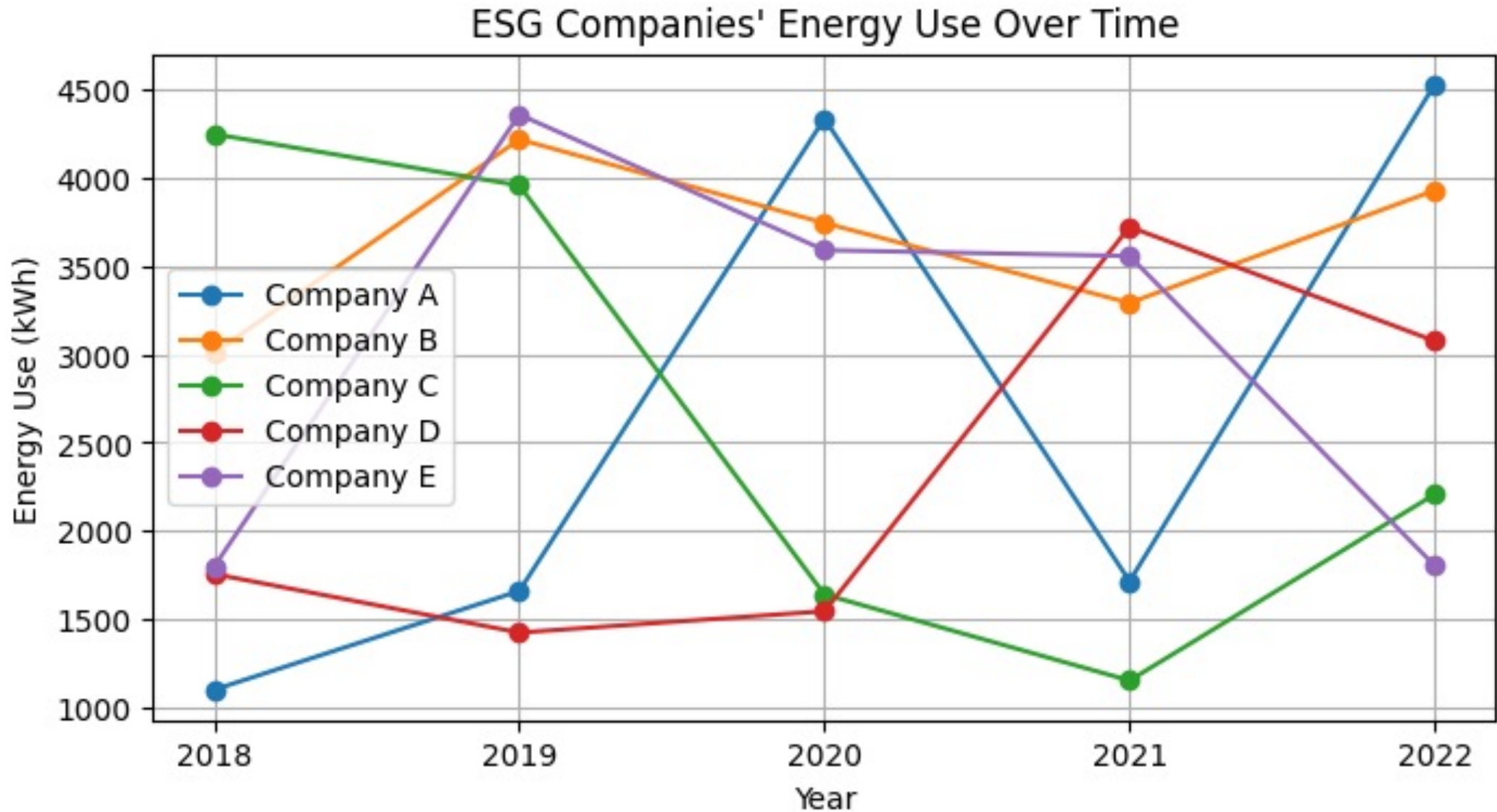
ESG Data Analysis and Visualization

```python
# Scatter Plot for Diversity vs. Satisfaction
plt.figure(figsize=(8, 4))
plt.scatter(correlation_data['diversity'],
correlation_data['employee_satisfaction'], alpha=0.7)
plt.xlabel('Board Diversity (Ratio)')
plt.ylabel('Employee Satisfaction (%)')
plt.title('ESG Correlation Between Board Diversity and Employee
Satisfaction')
plt.grid(True)
plt.show()
plt.savefig('ESG_Diversity_vs_Satisfaction.jpg', format='jpg', dpi=300)
```

ESG Data Analysis and Visualization

ESG Correlation Between Board Diversity and Employee Satisfaction
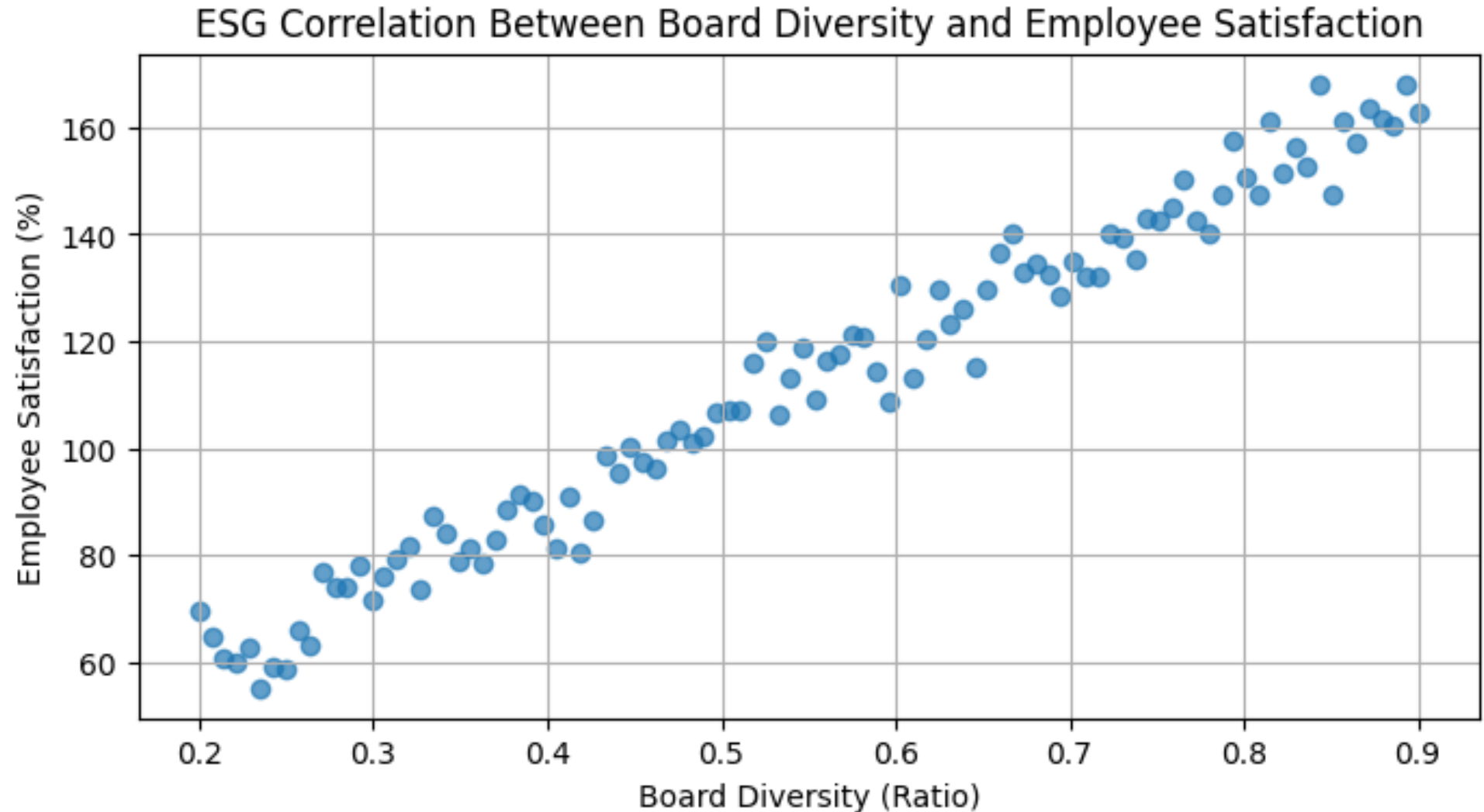
ESG Data Analysis and Visualization

```python
# Pie Chart for Waste Types
plt.figure(figsize=(8, 4))
plt.pie(df['waste_amount'], labels=df['waste_type'], autopct='%1.1f%%',
startangle=140)
plt.title('ESG Waste Types')
plt.axis('equal') # Equal aspect ratio ensures that pie is drawn as a
circle.
plt.show()
plt.savefig('ESG_Waste_Type_Breakdown.jpg', format='jpg', dpi=300)
```

ESG Data Analysis and Visualization

Python Pandas

http://pandas.pydata.org/
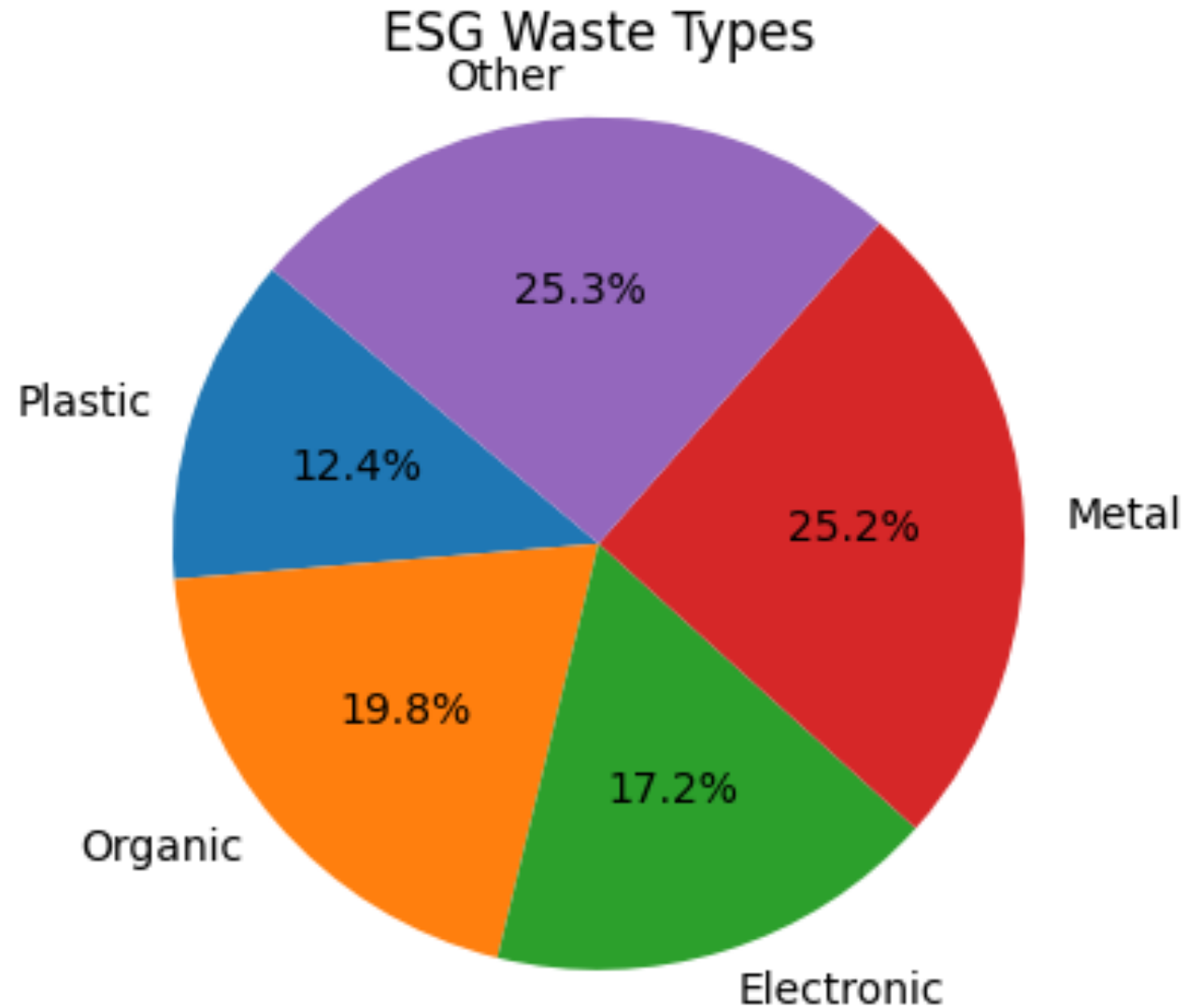
Python matplotlib

Python
seaborn

Source: https://seaborn.pydata.org/

Python
plotly

Python
bokeh

Python matplotlib

https://matplotlib.org/

https://seaborn.pydata.org/

Python Plotly Graphing Library

https://plotly.com/python/

Python Plotly Graphing Library

Fundamentals

More Fundamentals »

The Figure Data Structure
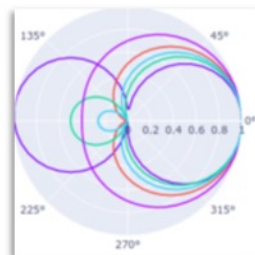
Creating and Updating Figures
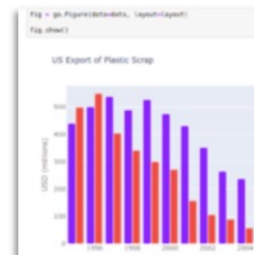
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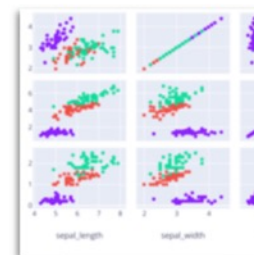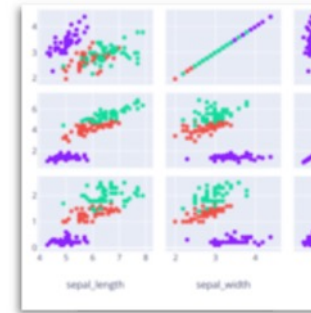
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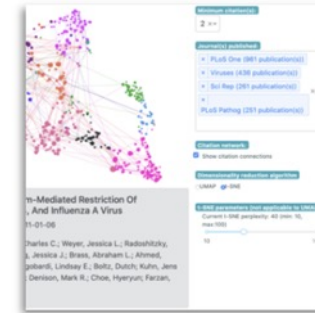
Analytical Apps with Dash

Artificial Intelligence and Machine Learning

More AI and ML »
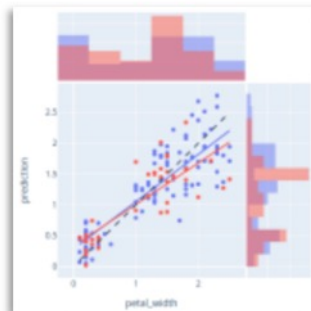
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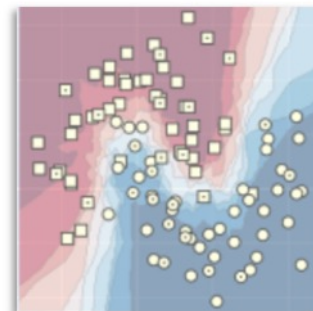
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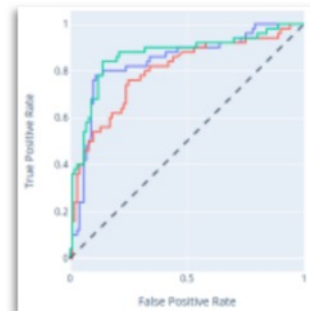
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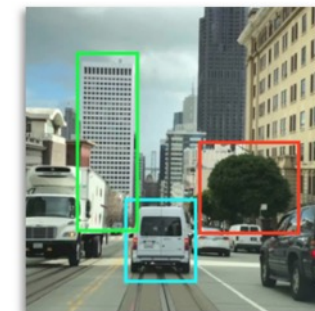
AI/ML Apps with Dash

https://plotly.com/python/

Python Plotly Graphing Library

Basic Charts

More Basic Charts »
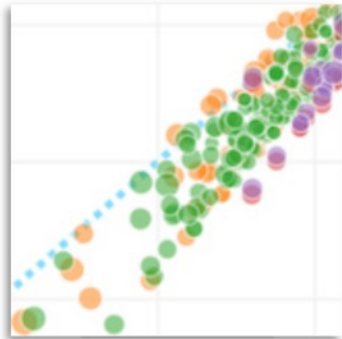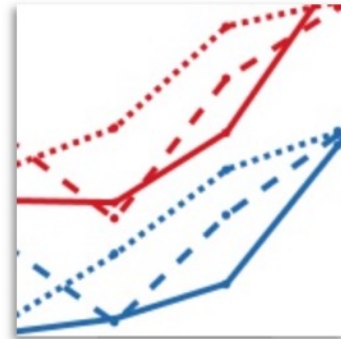
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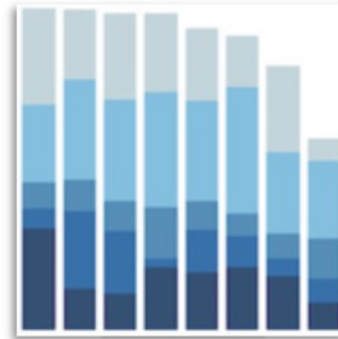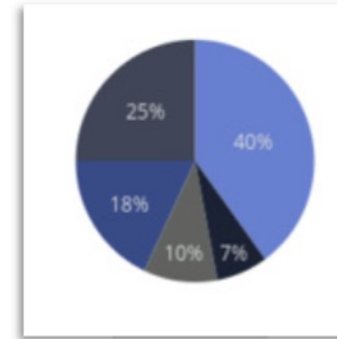
Statistical Charts

More Statistical Charts »
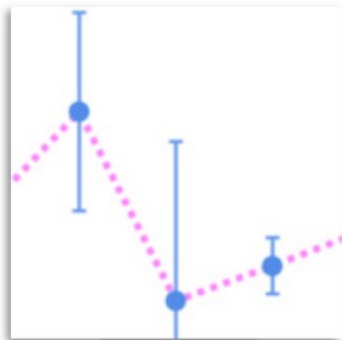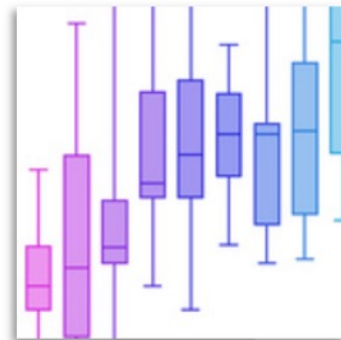
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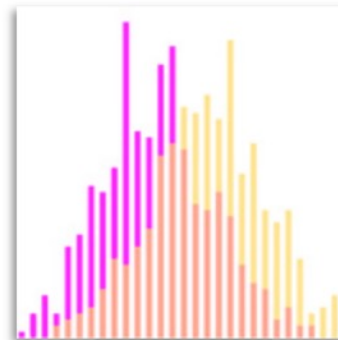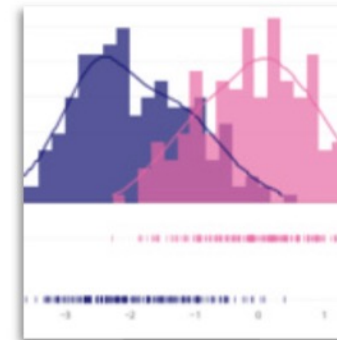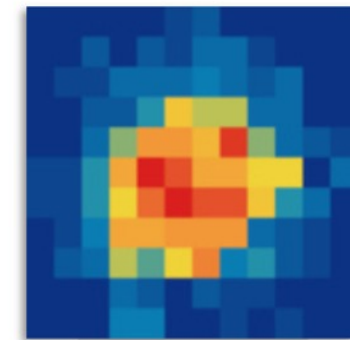
https://plotly.com/python/

Python Plotly Graphing Library

https://plotly.com/python/
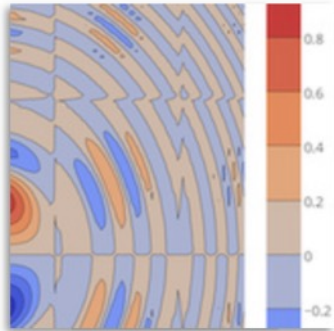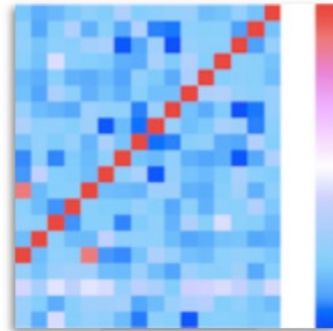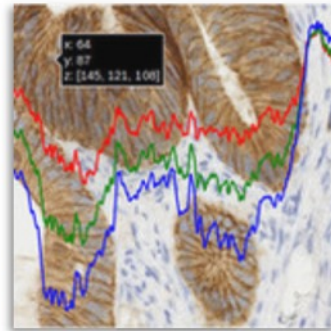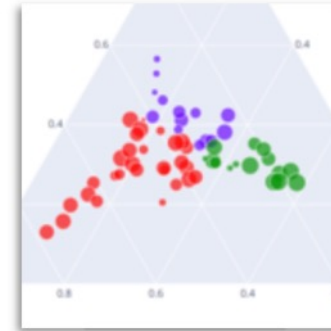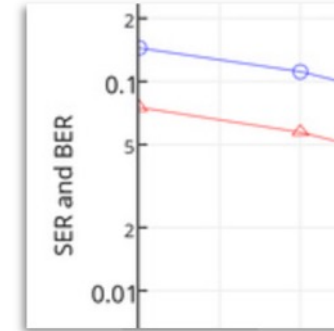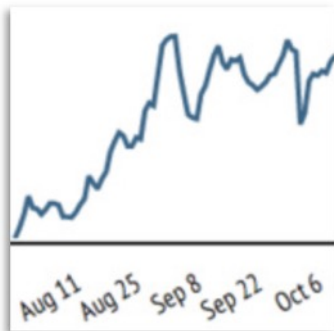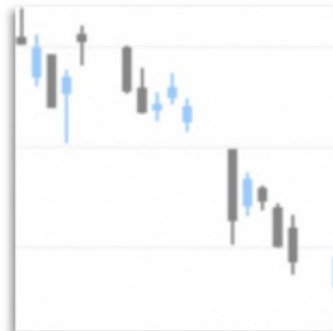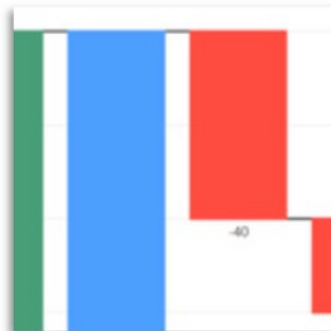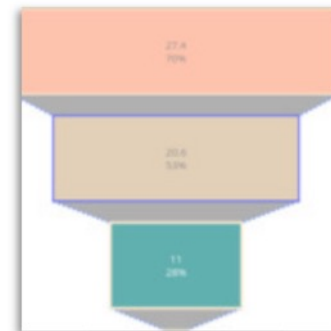
Python Plotly Graphing Library
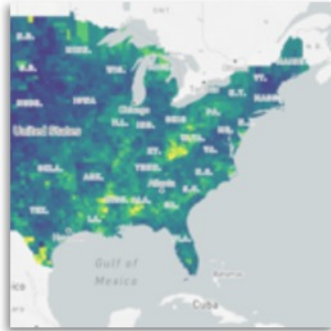
Maps

Mapbox Choropleth Maps	Lines on Mapbox	Filled Area on Maps	Bubble Maps	Mapbox Density Heatmap
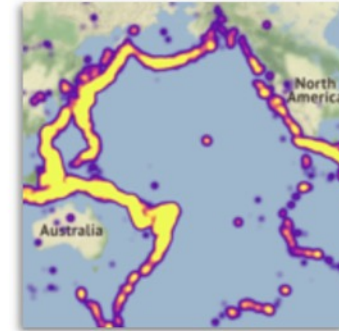
3D Charts
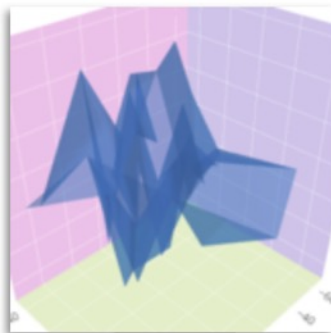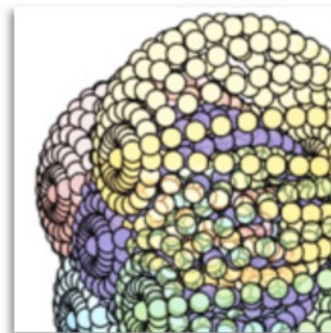
3D Axes	3D Scatter Plots	3D Surface Plots	3D Subplots	3D Camera Controls
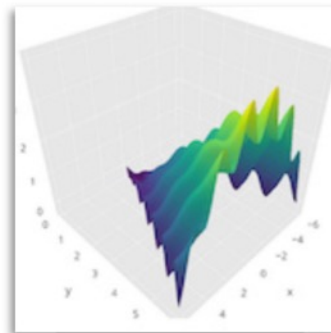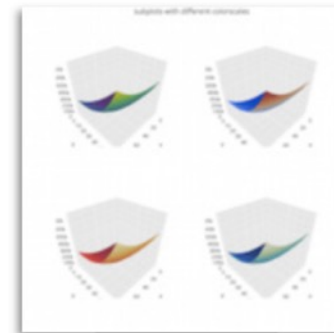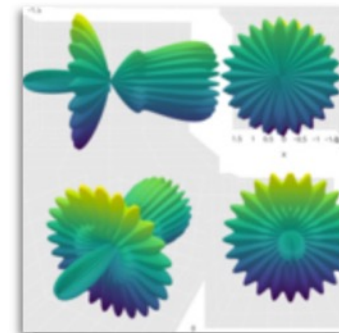
https://plotly.com/python/

Python Plotly Graphing Library

Subplots
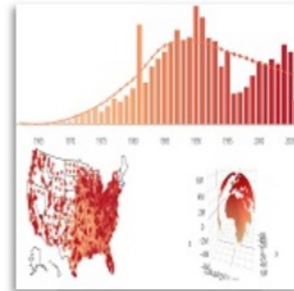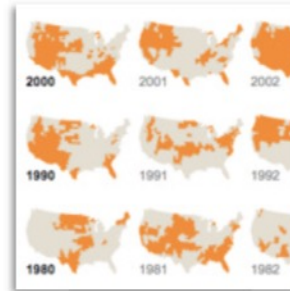
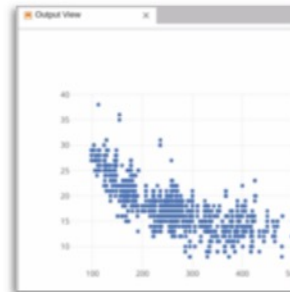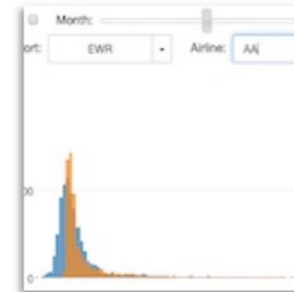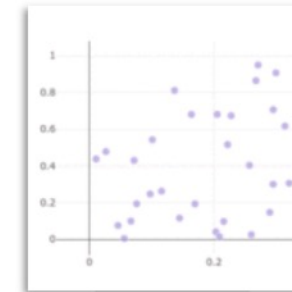| Mixed Subplots | Map Subplots | Table and Chart Subplots | Figure Factory Subplots |
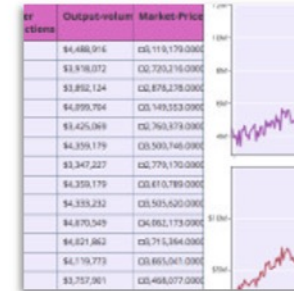
Jupyter Widgets Interaction
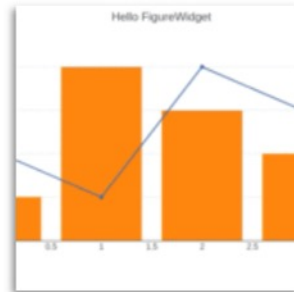
| Plotly FigureWidget Overview | Jupyter Lab with FigureWidget | Interactive Data Analysis with FigureWidget ipywidgets | Click Events |

https://plotly.com/python/

Python Bokeh

https://bokeh.org/
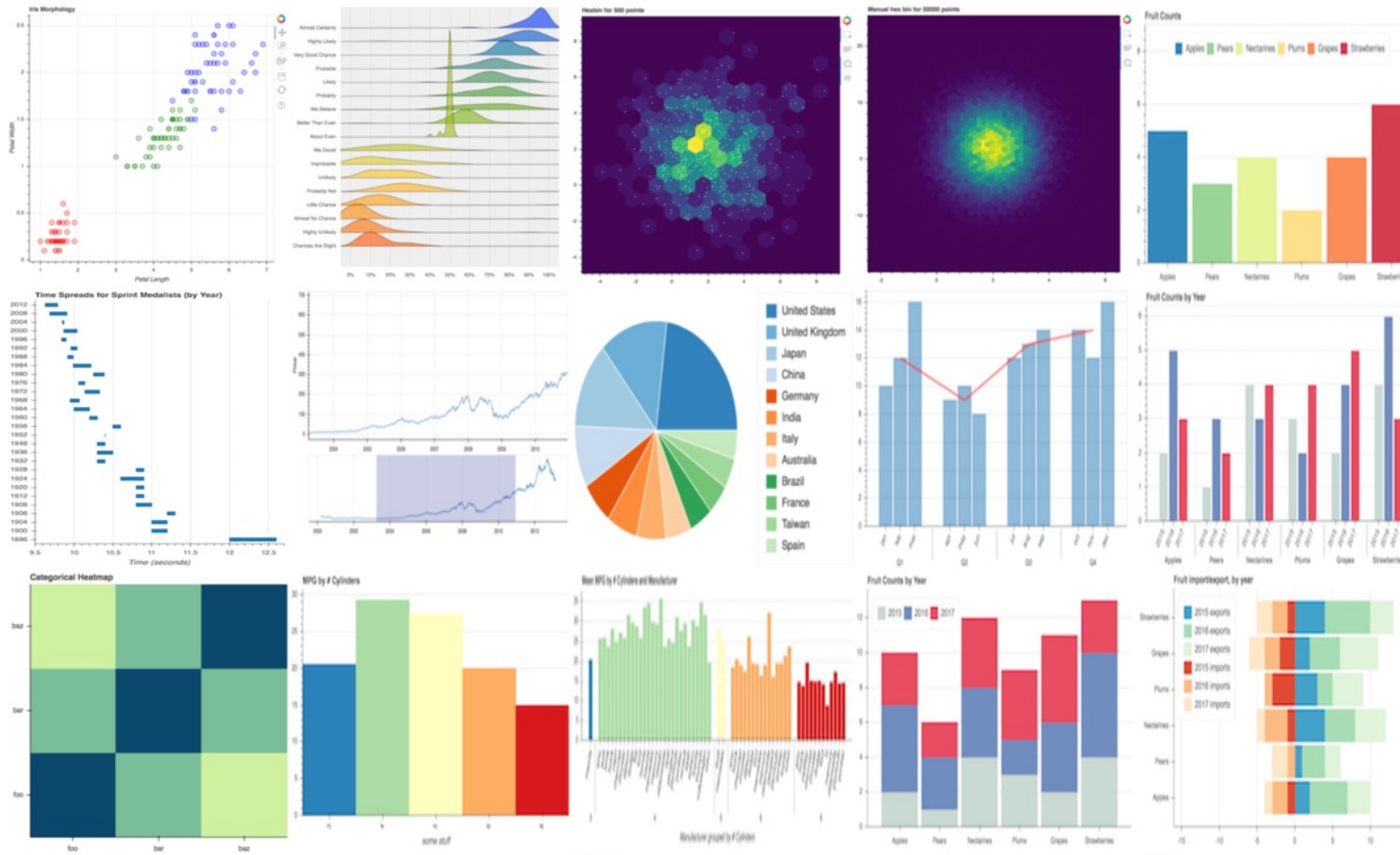
Python in Google Colab (Python101)

https://colab.research.google.com/drive/1FEG6DnGvwfUbeo4zJ1zTunjMqf2RkCrT

Summary

- **ESG Data Gathering**

- **ESG Data Analysis**

- **ESG Data Visualization**

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