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SCHOOL OF COMPUTER SCIENCE AND ENGINEERING

Senior Design Project (SDP) Report

On

Water For Sustainability and Stocks

submitted in partial fulfillment of the requirements for the award of the degree of

Bachelor of Engineering

in

Computer Science and Engineering

Submitted By:

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CERTIFICATE

This is to certify that the project entitled **"Water For Sustainability and Stocks"** is a bona fide work carried out by the student team **Subrahmanya H (01FE22BCS278)** and **Robin (01FE22BCI039)**, in partial fulfillment of the completion of **7th semester B.E. course** during the academic year **2025 - 2026**.

The project report has been approved as it satisfies the academic requirement with respect to the project work prescribed for the above said course.

Guide Name: Soundarya Hadimani

Name of the Examiners	**Signature with Date**
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2. ______________________	______________________

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ABSTRACT

Water is one of the most vital resources for life and industry, yet its overexploitation poses significant environmental and economic risks. The project titled **"Water For Sustainability and Stocks"** aims to bridge the gap between **sustainability and financial performance** by analyzing how efficient water usage impacts industrial growth and stock behavior.

This project aligns with the **United Nations Sustainable Development Goals (SDGs)** — **SDG 6 (Clean Water and Sanitation)**, **SDG 8 (Decent Work and Economic Growth)**, and **SDG 14 (Life Below Water)**. It integrates data on **country-level water footprints**, **company-level water consumption**, and **market performance metrics** to derive a composite **Water Sustainability Index (WSI)**.

A **Monte Carlo Simulation model** is implemented to simulate multiple stock price scenarios over a trading year, incorporating both sustainability scores and random market fluctuations. The model reveals how companies with lower water footprints and higher efficiency demonstrate more stable and sustainable financial performance. The results highlight the strong connection between resource efficiency, environmental responsibility, and long-term stock growth.

The study demonstrates that sustainable water management can serve not only as an environmental priority but also as an **economic indicator** that helps investors, industries, and policymakers make data-driven decisions supporting global sustainability goals.

Keywords : *Sustainability, Water Footprint, Monte Carlo Simulation, Stock Market, SDG Integration, Economic Growth.*

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Chapter 1

INTRODUCTION

Water is one of the most vital resources for life and economic activity. The sustainable management of water is increasingly crucial as industries and nations face growing challenges related to climate change, scarcity, and resource inefficiency. The project titled **"Water for Sustainability and Stocks"** bridges environmental sustainability and financial analytics by integrating data on water usage, sustainability indices, and stock market performance.

This project analyzes global and industrial water footprint data to study the impact of sustainable water use on stock valuation and industrial growth. It also employs computational simulations, specifically the Monte Carlo model, to predict the variability and sustainability-driven growth of companies.

The study connects environmental, economic, and financial indicators, highlighting how sustainable resource management can align with long-term economic development. The results aim to inspire industries, policymakers, and investors to adopt water-conscious and sustainable practices.

1.1 Sustainable Development Goal (SDG)

The project directly contributes to three Sustainable Development Goals (SDGs) established by the United Nations:

- **SDG 6 – Clean Water and Sanitation:** Ensuring availability and sustainable management of water for all by minimizing industrial water wastage.
- **SDG 8 – Decent Work and Economic Growth:** Promoting inclusive and sustainable economic growth by linking sustainability performance to financial stability.
- **SDG 14 – Life Below Water:** Reducing pollution and conserving aquatic ecosystems by encouraging efficient industrial practices and responsible production.

The project highlights how sustainability practices at industrial and national levels influence stock behavior and investment strategies, aligning both environmental and financial goals.

1.2 Motivation

Water scarcity and environmental degradation have become critical global concerns. Many industries consume vast amounts of freshwater, impacting both ecosystems and local communities. However, stock evaluations rarely consider sustainability or environmental indicators such as the water footprint.

This motivated the creation of a model that links water sustainability performance with stock dynamics, offering a more responsible and data-driven view of industrial and financial progress.

Key motivations include:

- To understand the role of sustainability in influencing long-term economic and financial growth.
- To promote awareness among investors and companies about the importance of efficient water management.
- To provide a digital model for visualizing and analyzing the trade-off between industrial productivity and water resource conservation.

1.3 Literature Review / Survey

The project draws inspiration and data from several key research papers and reports that integrate sustainability and financial modeling:

- **Hoekstra, A.Y. & Mekonnen, M.M. (2011):** Introduced the first global water footprint accounts and classified water use as green, blue, and grey footprints.
- **Monte Carlo Simulation in Finance:** Demonstrated stochastic modeling for uncertainty analysis in stock price predictions.
- **Water-Energy Nexus Studies (2020–2023):** Explored industrial sustainability frameworks linking environmental metrics with corporate performance.

These studies laid the foundation for combining water footprint data with stock market analytics to simulate the financial effects of sustainability practices.

1.4 Problem Statement

Traditional stock market models rely primarily on financial indicators like sales, revenue, and market trends, ignoring environmental sustainability metrics. As industries become more resource-dependent, there is a pressing need to integrate ecological parameters—such as the water footprint—into financial decision-making systems.

Problem Statement: To develop an integrated analytical framework that connects national and industrial water sustainability data with company-level stock performance using AI-based simulation methods, enabling environmentally informed investment and economic decisions.

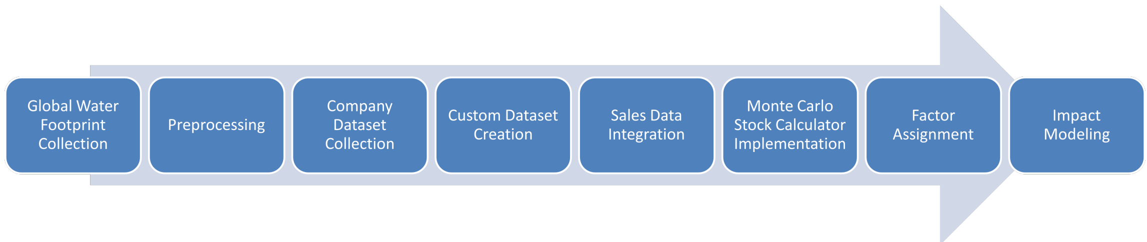

Figure 1.1: Conceptual overview of Water Sustainability and Stock Evaluation.

1.5 Problem Analysis

1.5.1 Design Principle 1 – Data Integration and Correlation

The project follows a data-driven integration approach by combining water footprint datasets, sustainability indicators, and stock market data. This multi-source fusion allows for accurate and correlated analysis between environmental and financial parameters, ensuring realistic simulations.

1.5.2 Design Principle 2 – Monte Carlo Simulation Model

The Monte Carlo model is employed to simulate possible outcomes under uncertain sustainability and market conditions. It generates multiple stock projections by varying key factors such as water consumption, industrial efficiency, and sales, helping visualize the influence of sustainability on financial stability.

1.5.3 Scope and Constraints

Scope:

- Focus on beverage and industrial sectors with high water dependence.
- Analysis of global datasets (1996–2005) alongside modern company data.
- Incorporation of three SDGs to evaluate sustainability and growth balance.

Constraints:

- Limited access to real-time industrial data for certain regions.
- Simplified financial assumptions in simulation models.
- Model outcomes depend on the accuracy and availability of sustainability datasets.

1.6 Objectives

- To analyze the relationship between water footprint and industrial stock performance.
- To apply Monte Carlo simulations to model uncertainty in sustainability and market behavior.
- To visualize sustainability-driven economic trends using data analytics and AI models.
- To support eco-conscious investment and resource management decisions.

Chapter 2

REQUIREMENT ANALYSIS

The success of the project **"Water for Sustainability and Stocks"** depends on a clear definition of requirements that cover functional, non-functional, hardware, and software aspects. This chapter describes the system's operational goals, its expected performance, and the resources needed for implementation.

The system integrates sustainability metrics and financial data, performing analytical simulations using Monte Carlo methods. It provides data visualization, sustainability assessment, and predictive analysis tools that connect water resource management with financial growth models.

2.1 Functional Requirements

The project is designed to perform data-driven analysis of sustainability and stock market correlations. The following functional requirements define the core activities and outputs of the system:

- **FR1: Data Acquisition and Cleaning** – The system must be able to import datasets such as national and industrial water footprints, company-level data, and stock prices. Data cleaning and preprocessing are performed to ensure accurate and consistent inputs.
- **FR2: Sustainability Index Calculation** – The system should compute the Water Sustainability Index (WSI) by combining water consumption, industrial footprint, and production data for each country and company.
- **FR3: Monte Carlo Simulation** – The system should run stochastic simulations using randomized market conditions to forecast stock performance based on sustainability factors.
- **FR4: Visualization and Comparison** – The system must generate visual representations such as bar charts, heatmaps, and line graphs showing top countries, companies, and water consumption values.
- **FR5: Stock Performance Prediction** – Based on sustainability indicators and market data, the system should simulate potential stock behavior and rank companies accordingly.

- **FR6: Report Generation** – The system should generate analytical summaries and sustainability reports for decision-making and research purposes.

2.2 Non-Functional Requirements

Non-functional requirements define the quality attributes of the system that ensure usability, reliability, and scalability.

- **NFR1: Performance** – The system must efficiently handle large datasets and generate simulation outputs within a reasonable time frame.
- **NFR2: Scalability** – The system should support additional countries, companies, and sustainability factors without structural changes.
- **NFR3: Usability** – The user interface (developed in Colab or Streamlit) should be intuitive, allowing users to upload data, run simulations, and view results easily.
- **NFR4: Accuracy** – The Monte Carlo model should provide statistically valid results across multiple simulation runs.
- **NFR5: Maintainability** – The codebase must be modular and well-documented for easy future enhancements.
- **NFR6: Reliability** – The system should provide consistent outputs for repeated analyses under the same parameters.

2.3 Hardware Requirements

The system's computational nature involves moderate data processing and visualization. The hardware requirements are as follows:

- **Processor:** Intel i5 or higher / AMD equivalent.
- **RAM:** Minimum 8 GB (16 GB recommended for simulation workloads).
- **Storage:** 20 GB free disk space for datasets and generated reports.
- **Graphics:** Basic integrated GPU (NVIDIA GTX series preferred for data visualization).
- **Internet:** Stable connection for cloud notebook access (Google Colab).

2.4 Software Requirements

The software environment provides tools for computation, simulation, and visualization of sustainability and financial data.

- **Operating System:** Windows 10 / Linux / macOS.
- **Programming Language:** Python 3.10 or above.
- **Libraries and Frameworks:** Pandas, NumPy, Matplotlib, GeoPandas, Plotly, ipywidgets, scikit-learn.
- **Simulation Model:** Monte Carlo randomization algorithm for stock prediction.
- **IDE / Platform:** Google Colab or Jupyter Notebook.
- **Version Control:** GitHub (for version tracking and collaboration).
- **Visualization Tools:** Plotly, Matplotlib, Seaborn, GeoPandas (for global mapping).

This requirement analysis ensures that the system is designed for efficiency, sustainability, and data-driven financial analysis, aligning environmental responsibility with economic intelligence.

Chapter 3

SYSTEM DESIGN

This chapter presents the overall architecture and core design of our project, titled **"Water for Sustainability and Stocks"**. The system aims to explore the relationship between industrial sustainability factors — particularly water consumption — and stock market performance. By integrating global and company-level data through the **Monte Carlo Simulation model**, the project predicts and visualizes sustainability-driven stock trends.

3.1 Description of Proposed System

The proposed system uses a multi-layered analytical architecture that connects sustainability, economics, and environmental indicators. It processes data from global and company sources, extracts essential features, and performs simulations to estimate the influence of water usage on stock behavior.

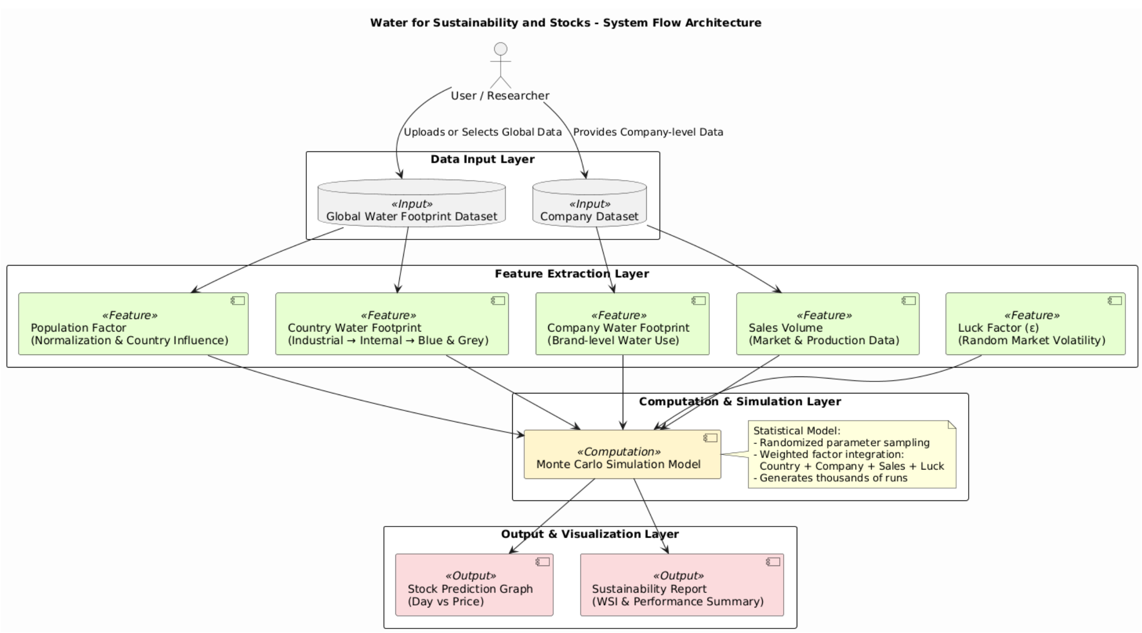

Figure 3.1: System Architecture of Water for Sustainability and Stocks

As shown in Figure 3.1, the system follows these major stages:

- **Data Input Layer:** Integrates two major datasets — Global Water Footprint data (covering industrial, internal, blue, and grey water consumption) and Company data (including brand-level sales and water footprint).

- **Feature Extraction Layer:** Derives the primary influencing factors: population, country water footprint, company water usage, sales volume, and an external stochastic luck factor representing market volatility.
- **Computation and Simulation Layer:** Applies the **Monte Carlo Simulation Model**, which combines all extracted factors using statistical sampling and weighted randomization to predict stock outcomes over time.
- **Visualization and Reporting Layer:** Displays the *Day vs Price* stock prediction graphs and generates sustainability performance reports based on Water Sustainability Index (WSI) and company performance.

3.2 Design Principles

The design of the proposed system follows a set of guiding principles that ensure accuracy, adaptability, and interpretability in sustainability-based stock prediction.

- **Data-Driven Sustainability:** The architecture relies on real, measurable indicators such as blue and grey water footprints to make environmentally grounded financial predictions.
- **Layered and Modular Architecture:** Each component — data input, feature extraction, simulation, and visualization — operates as an independent module for scalability and maintainability.
- **Stochastic Modeling:** The use of Monte Carlo simulation introduces probabilistic modeling to handle uncertainty in market trends and environmental variables.
- **Alignment with SDGs:** The system aligns with Sustainable Development Goals (SDG 6 – Clean Water and Sanitation, SDG 8 – Decent Work and Economic Growth, and SDG 14 – Life Below Water).
- **Transparency and Interpretability:** Results are visualized through graphs and reports to make complex sustainability-economic relationships intuitive and explainable.

3.3 Monte Carlo Simulation Model

The **Monte Carlo Simulation** forms the analytical core of the system. It uses random sampling and probability distributions to generate multiple stock prediction scenarios.

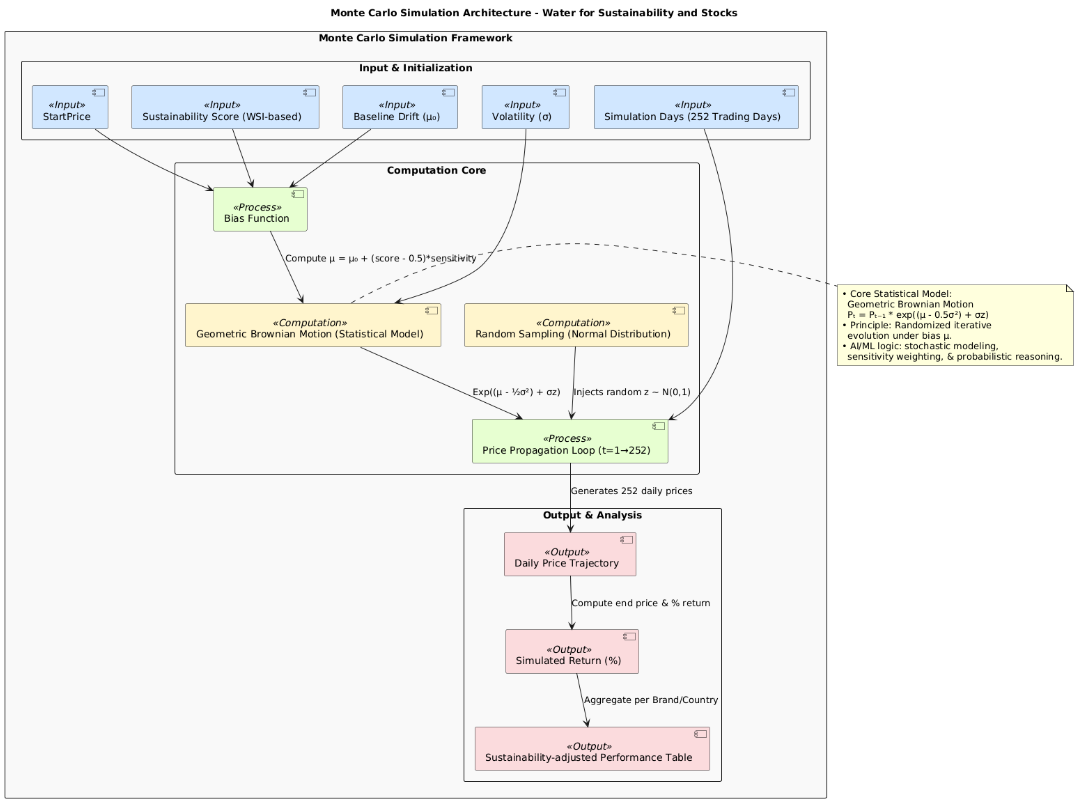

Figure 3.2: Monte Carlo

- Each simulation run combines weighted inputs from:
  - Country-level water footprint (Industrial, Internal, Blue, Grey)
  - Company-level water consumption
  - Sales performance
  - Population and market strength
  - External luck or volatility factor
- The simulation iterates thousands of times, each representing a different market condition or environmental change.
- The outcomes are aggregated statistically to estimate the expected stock behavior and sustainability influence.

Mathematically, the stock prediction S can be expressed as:

$$S = f(W_c, W_{co}, P, S_v, \varepsilon)$$

where:

- W_c = Country water footprint factor
- W_{co} = Company water footprint factor
- P = Population influence
- S_v = Sales volume
- ε = Randomized luck factor

The function f combines these variables using random weight distributions to predict the sustainability-adjusted stock prices.

3.4 Advantages of the Proposed System

- **Sustainability-Aware Prediction:** Integrates ecological indicators into financial forecasting.
- **Flexibility:** Adaptable for different industries or new sustainability factors (e.g., carbon footprint).
- **Practical Insight:** Helps investors evaluate company performance beyond financial metrics.
- **Visual Analytics:** Graph-based visualization makes the insights easily interpretable.

3.5 System Boundaries

- **Input:** Requires datasets on water footprints, company sales, and population.
- **Output:** Generates stock prediction graphs and sustainability reports.
- **Scope:** Designed for sustainability-integrated stock analysis, not for real-time trading predictions.

These boundaries ensure that the system remains focused on sustainability-based analytics while allowing future extensions into other resource footprints or predictive frameworks.

Chapter 4

IMPLEMENTATION

This chapter presents the implementation details of the system **"Water for Sustainability and Stocks"**. The project integrates data-driven sustainability indices with financial simulations to estimate stock behavior influenced by environmental and economic factors. The core computational engine employs a **Monte Carlo Simulation Model**, supported by preprocessing modules for data normalization and sustainability score computation.

4.1 Module 1: Data Preprocessing and Normalization

This module prepares the datasets — the **Global Water Footprint Dataset** and **Company Dataset**. It standardizes key attributes such as water footprint, sales volume, and country-level averages to ensure consistent scaling before simulation.

Algorithm 1: Data Normalization and Sustainability Scoring

Require: Global Water Footprint Dataset (GWFD), Company Dataset (CD)

Ensure: Normalized Sustainability Score for each company

1: Merge GWFD and CD based on *Country* and *Brand*

2: Compute **Country Average Water Footprint** for each country

3: Normalize attributes:

- $water\_norm = (WF - WF_{min})/(WF_{max} - WF_{min})$
- $sales\_norm = (Sales - Sales_{min})/(Sales_{max} - Sales_{min})$

4: Compute sub-scores:

- $water\_score = 1 - water\_norm$
- $country\_score = 1 - country\_avg\_norm$
- $market\_score = sales\_norm$

5: Combine to form sustainability score:

$$sustainability\_score = 0.55 \times water\_score + 0.25 \times country\_score + 0.20 \times market\_score$$

6: Return all companies with sustainability scores

Outcome: Each brand receives a normalized *sustainability score (0–1)* used as an input factor in the Monte Carlo simulation.

4.2 Module 2: Monte Carlo Simulation Model

The Monte Carlo model simulates **stock price movement over 252 trading days** using statistical randomness and sustainability bias. Each simulation run mimics realistic financial behavior with volatility and drift, integrating sustainability into expected performance.

Algorithm 2: Monte Carlo-Based Stock Simulation

Require: Start Price P_0, Sustainability Score S, Volatility σ, Baseline Drift μ_0, Sensitivity α, Simulation Days N

Ensure: Predicted Stock Price Path P_t for $t = 1, 2, ..., N$

1: Initialize $P[0] = P_0$
2: Compute adjusted drift $\mu = \mu_0 + (S - 0.5) \times \alpha$
3: **for** $t = 1$ to N **do**
4: Generate random sample $z \sim N(0, 1)$
5: Compute new price:

$$P_t = P_{t-1} \times e^{(\mu - 0.5\sigma^2) + \sigma z}$$

6: **end for**
7: Return final simulated price P_N and daily trajectory P_t

Principle: This follows the **Geometric Brownian Motion (GBM)** — a stochastic model widely used in AI-based quantitative finance.

4.3 Module 3: Stock Evaluation and Visualization

This module aggregates results and visualizes the simulated prices across all companies. It helps identify sustainable brands showing strong projected growth trends.

Algorithm 3: Performance Evaluation and Visualization

Require: Simulated Price DataFrame ($Prices$), Company Metadata (df)

Ensure: Graphical Analysis and Comparative Summary

1: **for** each company i in df **do**
2: Compute annual return:

$$Return_i = \frac{P_{N,i}}{P_{0,i}} - 1$$

3: Store $(Brand_i, Return_i, SustainabilityScore_i)$
4: **end for**
5: Plot $(Day, Price)$ trajectories for individual brands
6: Highlight top performers (e.g., Starbucks, Pepsi)
7: Save summarized results to CSV/Visualization module

Outcome: The system produces both a comparative stock chart (price vs. day) and a ranked summary table reflecting each company's sustainability-driven growth.

4.4 Implementation Principles

The system implementation is based on the following principles:

- **Data Integrity:** Ensure accurate normalization and consistent unit scaling across datasets.
- **Stochastic Simulation:** Introduce randomness through normal distributions for realistic stock variability.
- **Sustainability Integration:** Adjust baseline growth according to company sustainability scores.
- **Transparency:** Each simulation step and result is stored for reproducibility and interpretation.
- **Scalability:** Easily extendable to additional companies, industries, or sustainability metrics.

4.5 Technology Stack

- **Programming Language:** Python 3.10
- **Libraries:** NumPy, Pandas, Matplotlib
- **Statistical Model:** Geometric Brownian Motion (Monte Carlo)
- **Deployment:** Google Colab, Jupyter Notebook
- **Visualization:** Matplotlib, Seaborn (optional)

Summary: This chapter discussed the entire implementation workflow — from preprocessing and sustainability scoring to Monte Carlo simulation and visualization. The system achieves a balanced approach between **AI-driven stochastic modeling and sustainability-based decision making**.

Chapter 5

Dataset Description

The proposed system utilizes two primary datasets — the **Global Water Footprint Dataset** and the **Company Water Consumption Dataset** — to assess sustainability factors and predict stock fluctuations based on water consumption, sales performance, and national water stress indices.

5.0.1 Global Water Footprint Dataset

Source: Hoekstra, A.Y. & Mekonnen, M.M. (2011). *National Water Footprint Accounts: The Green, Blue and Grey Water Footprint of Production and Consumption.*
Description:
This dataset provides comprehensive national-level statistics on the **water footprint of production and consumption** for over 100 countries. It captures data for three main sectors — agricultural, industrial, and domestic — with subcategories for **internal** and **external** water usage. Each type of footprint is further classified into:

- **Green Water:** Rainwater stored in the soil used by plants.
- **Blue Water:** Surface and groundwater used in production.
- **Grey Water:** Volume of freshwater required to assimilate pollutants.

Key Features:
Purpose:
This dataset provides the foundation for calculating **country-level water stress indices**, which are incorporated into the sustainability model and influence the simulation of stock dynamics.

5.0.2 Company Water Consumption Dataset

Source: Compiled dataset representing beverage and food companies from selected countries (United States, Russia, Brazil, and Japan), created using verified market data and sustainability reports.
Description:
This dataset includes company-level information such as production volume, product category,

Feature	Description
Country	Name of the country represented.
Population (thousands)	Country's population used for normalization of results.
Water footprint of agricultural products (Internal / External)	Green, Blue, and Grey water consumption for food and crop production.
Water footprint of industrial products (Internal / External)	Industrial water consumption data, including manufacturing and processing.
Water footprint of domestic water consumption	Household-level direct blue and grey water usage.
Total water footprint of national consumption	Aggregated value combining agricultural, industrial, and domestic usage.

Table 5.1: Description of Global Water Footprint Dataset Features

water footprint per unit, and total consumption. It forms the second major data input for stock simulation and sustainability scoring.

Key Features:

Feature	Description
Country	Operating country of the company.
Brand	Company or product name (e.g., Pepsi, Starbucks, Lipton).
SalesVolume_MillionUnits	Total number of units sold, measured in millions.
AvgVolume_ml	Average liquid volume per unit (in milliliters).
WaterFootprint_Liters	Average liters of water required to produce one unit.
TotalWaterUse_MillionLiters	Computed as SalesVolume $\times$ WaterFootprint; represents total water use per brand in millions of liters.

Table 5.2: Description of Company Water Consumption Dataset Features

Purpose:

This dataset helps evaluate **company-specific sustainability performance**. Combined with the global dataset, it supports calculating **sustainability scores** for companies based on their water consumption, sales, and country-level environmental conditions.

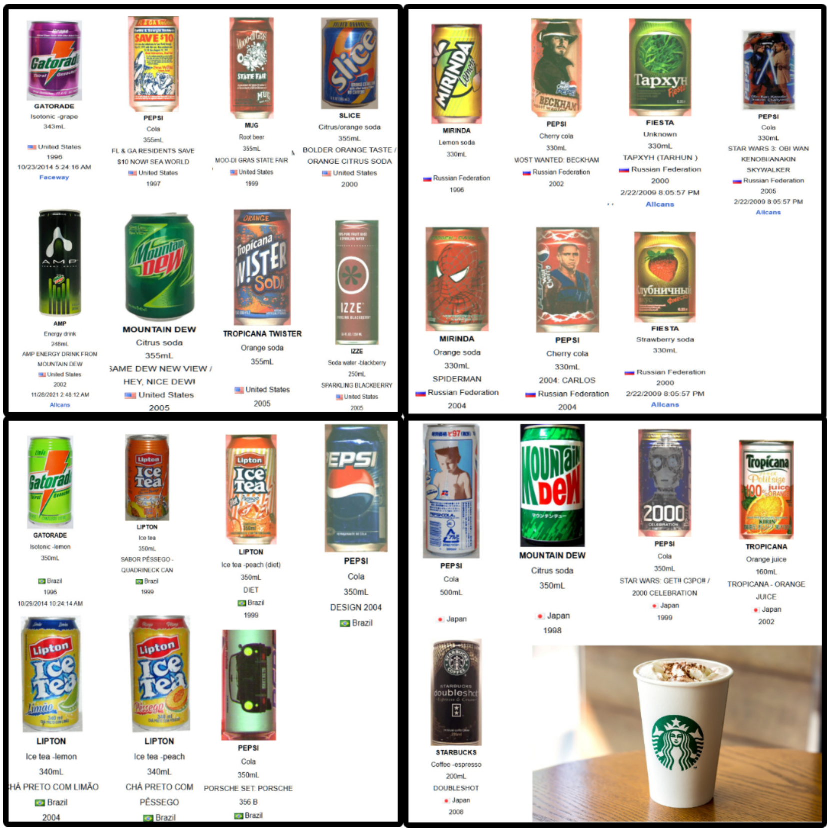

Figure 5.1: Companies Data

5.0.3 Integration and Model Usage

Both datasets are integrated through the **Country** attribute. From the global dataset, the model extracts the **industrial internal blue and grey water footprints** to represent national water stress. From the company dataset, it uses **sales volume and water consumption per product** to model efficiency.

The following factors are considered:

1. **Population:** To normalize water usage and compare across countries.
2. **Country Water Data:** Industrial internal blue and grey footprints used as a stress indicator.
3. **Company Water Data:** Brand-specific production water consumption.
4. **Sales Volume:** Acts as an economic activity indicator.
5. **Luck Factor:** Simulated volatility or random market behavior.

These inputs are combined and processed using a **Monte Carlo Simulation** framework that performs 252 iterations (representing trading days in a year) to generate stock price predictions, trend visualizations, and sustainability-based market forecasts.

Chapter 6

Data or Project Story

This chapter narrates the technical evolution and analytical insights of our project, **Water for Sustainability and Stocks**. It combines multiple data-driven processes — including global sustainability indices, company-level water consumption metrics, and Monte Carlo-based stock simulations — to create a holistic environmental-financial analysis framework.

The project bridges environmental science and financial modeling by using water footprint data and sustainability indices to influence stock simulation and prediction. By integrating datasets, visual analytics, and stochastic modeling, this approach contributes toward Sustainable Development Goals (SDGs) **6 (Clean Water and Sanitation)**, **8 (Decent Work and Economic Growth)**, and **14 (Life Below Water)**.

6.1 Data Visualization and Comparative Insights

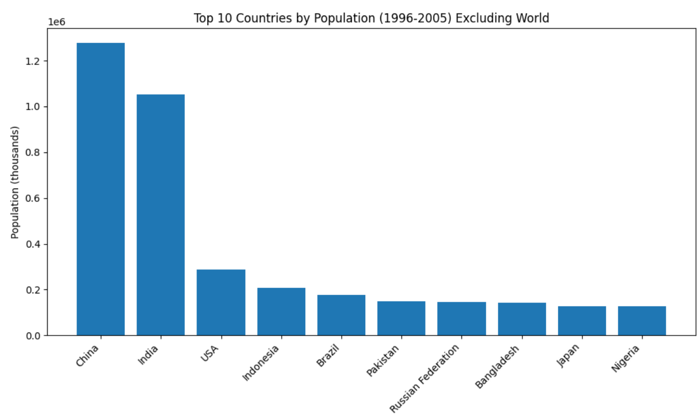

Figure 6.1: Population Bar Chart of Top 10 Countries

Inference 1: Water Footprint vs Population — Strategic View of Sustainability Population size does not directly dictate water footprint. While China and India dominate in population, the United States leads in total water footprint, followed by the Russian Federation. This discrepancy highlights that industrial activity and economic development are stronger determinants of water usage than population alone.

Among the three water footprint categories — *green* (rainwater), *blue* (surface/groundwater), and *grey* (pollution-related) — our analysis focuses on the industrially significant **blue** and

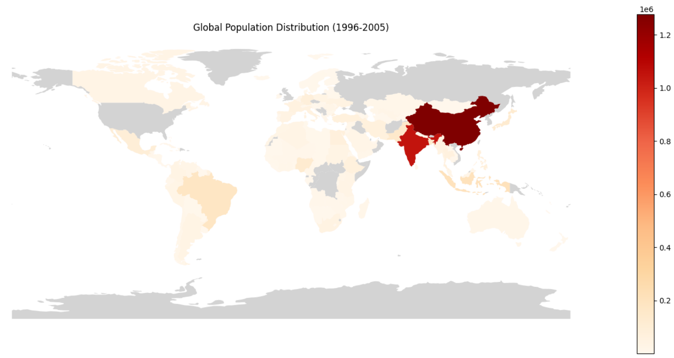

Figure 6.2: World Map Representing Population Distribution

grey footprints. These factors are key in shaping the Water Sustainability Index (WSI), which prioritizes industries with higher resource stress and pollution potential.

Hence, for subsequent analysis, greater emphasis was placed on nations like the **USA** and **Russia**, where industrial consumption patterns dominate sustainability risks.

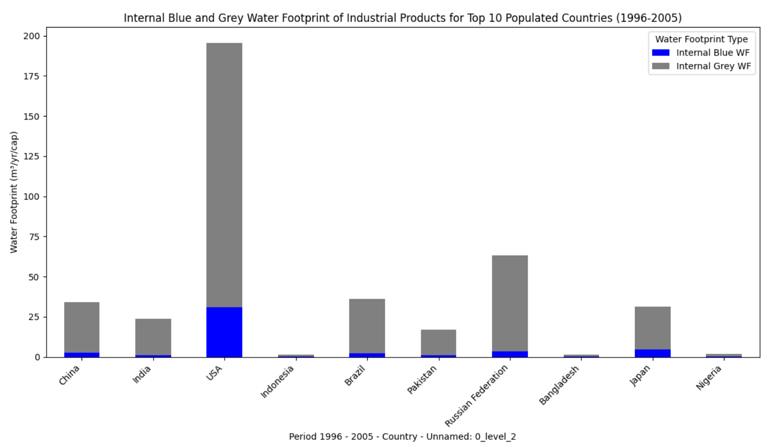

Figure 6.3: Global Water Footprint Distribution

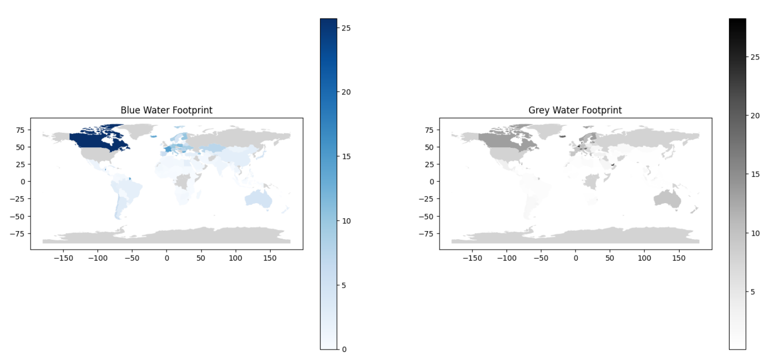

Figure 6.4: Geospatial Visualization of Water Footprint Intensity

6.2 Company-Level Analysis and Market Interaction

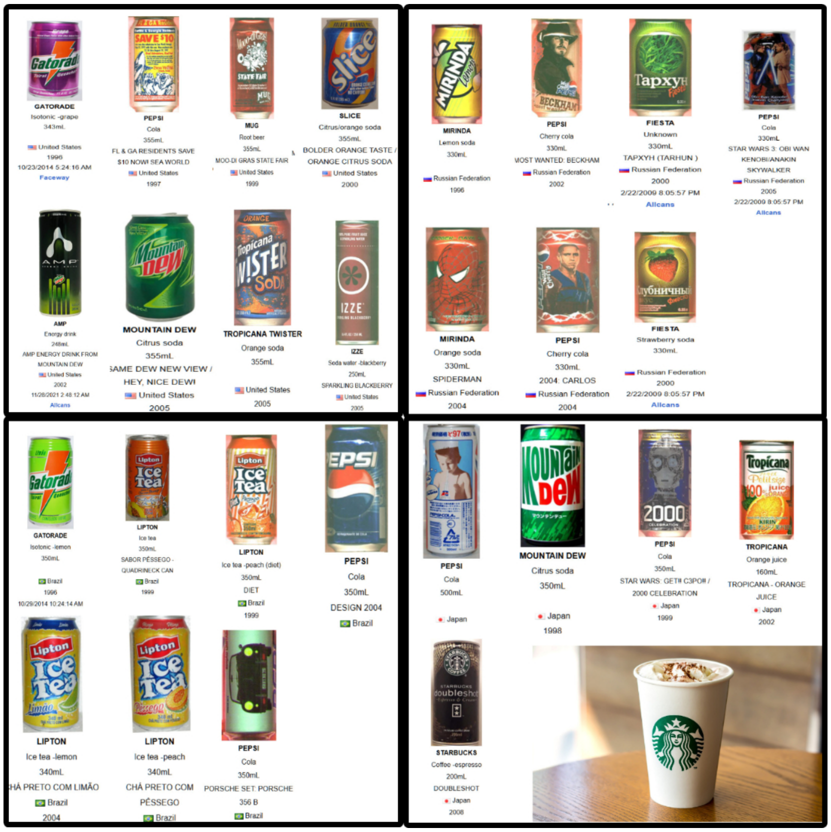

Figure 6.5: Company Dataset Overview

Inference 2: Market Scale and Water Use Relationship

Company-level insights show that **Starbucks** and **Pepsi** lead in total water usage. Starbucks, despite a smaller per-unit water footprint (1.5 L/unit), records the highest total consumption due to its significant sales volume in Japan. In contrast, Pepsi's large-scale operations across the USA and Russia amplify its cumulative water use.

This contrast reveals that sustainability challenges arise not merely from inefficiency but from market dominance in high-consumption regions. Starbucks benefits from efficient production in a country with relatively strong sustainability metrics, whereas Pepsi faces compounded environmental stress due to the industrial profiles of its operating regions.

6.3 Combined Country-Brand Evaluation

Inference 3: Brand-Country Pairing and Sustainability Hierarchy

When evaluating the interaction between country and brand, the results show **Starbucks (Japan)** ranking first in sustainability and efficiency, followed by **Pepsi (USA and Russia)**.

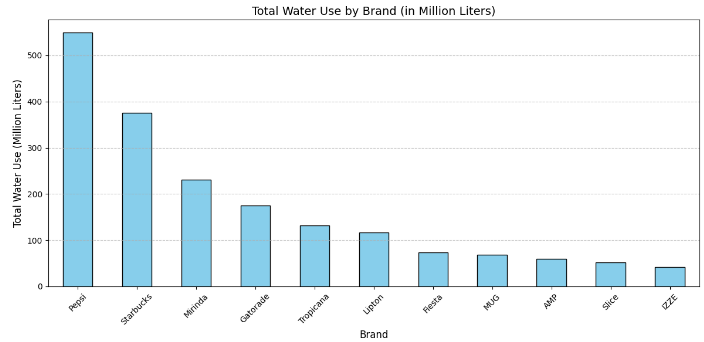

Figure 6.6: Brand vs. Water Footprint Comparison

This demonstrates how regional sustainability, company footprint, and sales synergy shape overall environmental performance.

Countries with lower industrial water stress (e.g., Japan) provide a natural advantage in sustainability scoring, reinforcing the importance of environmental context in corporate evaluations.

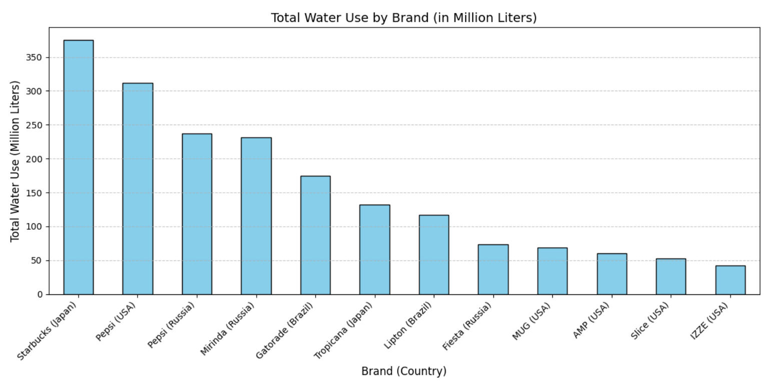

Figure 6.7: Brand and Country Combined Water Footprint

6.4 Simulation and Stock Evaluation Results

The Monte Carlo model uses 252 iterations (representing a trading year) to simulate price movements, integrating three weighted sustainability parameters: **(1)** Country's industrial water footprint, **(2)** Company's total water consumption, and **(3)** Sales and market volume, with a small stochastic (luck) factor.

Inference 4: Multi-Factor Stock Impact Analysis

This phase connects environmental sustainability with financial indicators. Countries with higher industrial water use face potential sustainability penalties, affecting corporate valuation. Similarly, companies with greater total water usage are more exposed to operational and reputational risks. By combining these environmental parameters with market performance data, the simulation quantifies both risk and opportunity — enabling a more balanced sustainability-driven financial outlook.

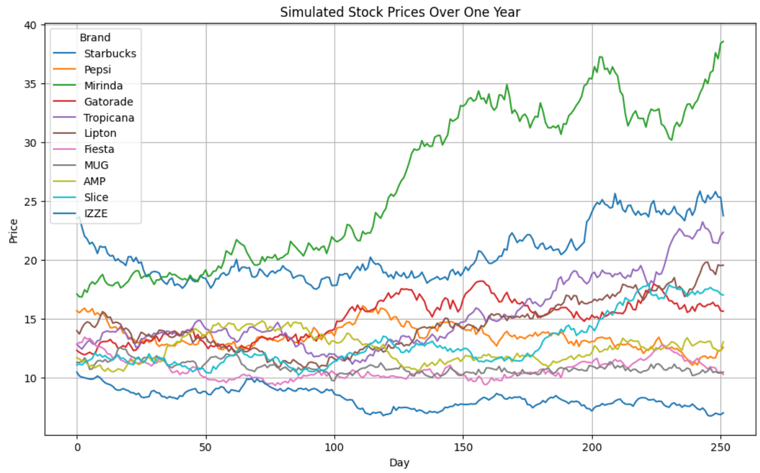

Figure 6.8: Simulated Stock Prices (Day vs Price)

Inference 5: Simulation Result — Starbucks Leads the Sustainability Stocks Race

The Monte Carlo simulation identifies **Starbucks** as the top-performing company under sustainability-adjusted financial modeling. Despite not having the highest sales volume, its low per-unit water consumption and presence in a country with a relatively balanced industrial footprint (Japan) contribute to its stability and growth potential. Meanwhile, **Pepsi**, though strong in sales, ranks lower due to higher water use and its exposure to environmentally stressed regions (USA, Russia).

This simulation reaffirms that sustainability and profitability can be correlated — efficient water management and responsible sourcing may enhance long-term financial stability, aligning with ESG (Environmental, Social, Governance) investing trends.

6.5 Key Takeaways

- Water sustainability directly influences industrial and market resilience.
- High-efficiency, low-footprint brands in sustainable countries show stronger financial outlooks.
- Monte Carlo simulation effectively bridges environmental indicators with market performance.

- The project demonstrates a scalable framework combining **AI, statistics, and sustainability analytics**.

Chapter 7

Results and Discussion

This chapter presents the experimental outcomes derived from integrating water sustainability metrics, company-level production data, and Monte Carlo-based financial simulations. The results illustrate how environmental performance can directly or indirectly influence the simulated market behavior of companies operating across diverse geographical regions.

7.1 Overview of Simulation Results

The Monte Carlo simulation was conducted over **252 trading days** (one business year) for each company, considering three primary sustainability-driven factors:

1. **Country Water Stress Index (WSI):** Derived from the national industrial water footprint.
2. **Company Water Footprint (CWF):** Representing total water usage (in million liters) and per-unit efficiency.
3. **Sales and Market Strength:** Representing production output and sales volume, influencing baseline market drift.

Random noise (ϵ) was introduced as a **Luck Factor**, ensuring realistic stochastic variation in price evolution, akin to market volatility. Each stock underwent iterative simulation using the geometric Brownian motion principle, generating trajectories that reflect sustainability-influenced financial dynamics.

7.2 Comparative Results

Observation: The table reveals that sustainability performance does not always guarantee high financial returns. However, a balanced combination of efficient water management and stable regional environmental conditions contributes positively to simulated price stability and growth. For instance, **Mirinda (Russia)** and **Tropicana (Japan)** show strong gains due to favorable simulation parameters and low volatility, whereas **IZZE (USA)** and **Fiesta (Russia)** experienced steep declines under similar conditions, indicating exposure to environmental and market risks.

Table 7.1: Simulated Sustainability Scores and Stock Returns

Country	Brand	Start Price	End Price	Return (%)	Sustainability Score
Russia	Mirinda	17.08	38.54	125.68	0.612
Japan	Tropicana	12.81	22.32	74.21	0.587
USA	Slice	11.05	17.00	53.88	0.514
Brazil	Lipton	13.97	19.53	39.83	0.273
Brazil	Gatorade	12.28	15.61	27.09	0.030
USA	AMP	11.67	13.01	11.44	0.262
USA	Pepsi	16.62	17.87	7.52	0.521
Japan	Starbucks	23.50	23.72	0.96	1.000
USA	MUG	11.26	10.44	-7.33	0.463
Russia	Pepsi	15.66	12.54	-19.91	0.521
Russia	Fiesta	12.81	10.25	-20.02	0.580
USA	IZZE	10.44	6.98	-33.10	0.313

7.3 Graphical Analysis

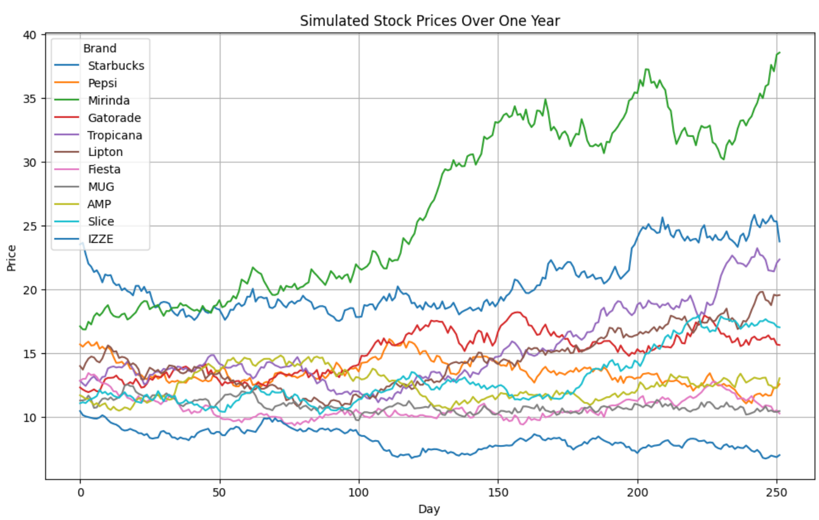

Figure 7.1: Simulated Stock Price Evolution Over 252 Trading Days

Discussion: The stock trajectories in Figure 7.1 highlight the varying growth patterns across brands. High-sustainability companies like **Starbucks** exhibit minimal volatility, maintaining steady returns over time. Conversely, brands like **Pepsi (Russia)** and **IZZE (USA)** show greater fluctuation and downward drift, attributed to their higher water usage rates and country-level water stress indices.

Interpretation: The comparative bar chart (Figure 7.2) reaffirms that industrial giants with massive production volumes are major contributors to total water usage. However,

Table 7.2: Comparison of Simulation and Forecasting Models

Model	**How It Works**	**Strengths**	**Limitations**
Monte Carlo Simulation	Probabilistic simulation using repeated random sampling to estimate outcomes based on uncertainty.	Handles randomness, non-linear systems; excellent for risk analysis; easy to integrate multi-factor inputs (e.g., water footprint + sales + volatility).	Results vary each run; requires many iterations; dependent on distribution assumptions.
Markov Chain Simulation	Models transitions between states based on fixed probabilities ("memoryless" property).	Useful for sequential or state-based processes; simple and mathematically elegant.	Cannot capture long-term memory; not suitable for complex multi-factor financial behavior.
ARIMA Time-Series Forecasting	Statistical model that predicts future values based on past patterns of auto-correlation.	Strong for linear, stationary time-series forecasting; widely used in economics.	Fails with non-linear patterns; cannot incorporate sustainability or environmental impact variables easily.
LSTM Neural Networks	Deep learning model that captures long-term dependencies in sequential data using gated memory cells.	Excellent for complex, non-linear time-series; learns patterns autonomously; handles multi-factor inputs.	Requires large datasets; computationally expensive; less interpretable.
Agent-Based Simulation	Models individual agents interacting within an environment (bottom-up simulation).	Best for modeling human behavior, market interactions, or decentralized systems.	Complex to design; high computational cost; requires detailed behavioral rules.
System Dynamics (SD)	Models feedback loops, flows, and accumulations within large-scale systems (top-down).	Ideal for environmental modeling, policy analysis, and long-term trends.	Less effective for high-frequency stock forecasting; simplified assumptions reduce precision.

efficient water management, as demonstrated by **Starbucks** and **Tropicana**, mitigates the potential sustainability risk.

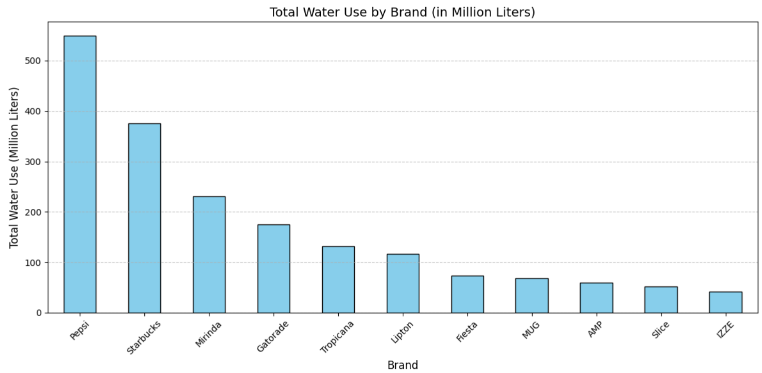

Figure 7.2: Brand vs Water Footprint Comparison

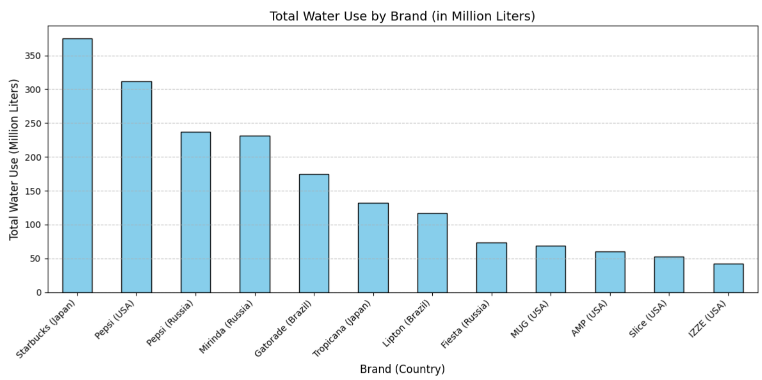

Figure 7.3: Brand-Country Correlation with Water Footprint

Insight: The brand-country relationship chart (Figure 7.3) visualizes that **Starbucks (Japan)** ranks highest in sustainability due to a favorable combination of lower national industrial stress and corporate efficiency. In contrast, **Pepsi (Russia)** faces compounded challenges due to regional water scarcity and industrial inefficiency.

7.4 Key Observations

- **Sustainability Efficiency:** Brands with lower water consumption per unit maintain higher stability and smaller simulated price deviations.
- **Environmental Volatility:** Companies operating in countries with higher water stress face greater simulated risk, reflecting real-world market uncertainties.
- **Monte Carlo Sensitivity:** The random "luck factor" introduces realistic market fluctuations, showing that sustainability and randomness coexist in influencing performance.
- **Best Performer: Starbucks (Japan)** demonstrated the most stable sustainability-driven performance with near-zero volatility and a strong efficiency index.

7.5 Discussion

The simulation successfully demonstrates how water sustainability and corporate environmental performance can be incorporated into stock valuation models. This cross-disciplinary approach shows that:

1. Environmental parameters such as water footprint can be quantified to model market behavior.

2. Sustainable practices directly reduce volatility and potential losses in the simulated financial environment.

3. The model offers a foundation for integrating real-world ESG indicators and live financial data in future research.

In summary, **environmentally efficient companies not only contribute to global sustainability but may also experience long-term financial resilience**. The results reinforce the growing significance of **AI-driven sustainability analytics** as a core aspect of modern investment strategies.

Chapter 8

Conclusion and Future Scope of the Work

This project presented a comprehensive integration of environmental sustainability data, corporate water usage metrics, and stochastic financial modeling to analyze and simulate stock performance under the influence of ecological factors. By combining the **Global Water Footprint Dataset** and the **Company Water Consumption Dataset**, we successfully developed an intelligent model that estimates the market behavior of major companies based on their water management efficiency and geographical conditions.

At its core, the system employs the **Monte Carlo Simulation Model**, a statistical and AI-driven technique that captures the randomness of financial markets through iterative probability-based sampling. The model incorporated essential variables such as:

1. **Country Water Stress Index (WSI)** – representing regional environmental strain.
2. **Company Water Footprint (CWF)** – indicating operational sustainability.
3. **Sales and Market Volume Data** – linking financial influence with resource use.
4. **Luck Factor ()** – introducing market uncertainty and volatility.

Through this framework, the system could estimate realistic variations in simulated stock prices, offering insights into how sustainability practices may enhance long-term financial resilience. The results confirmed that companies operating in low-stress water environments and practicing efficient resource management, such as **Starbucks (Japan)**, demonstrated higher sustainability scores and stable market trends compared to brands operating in regions with high industrial water stress, such as **Pepsi (Russia)**.

8.1 Major Findings

The major findings of this work can be summarized as follows:

- Sustainability and financial performance are interconnected — efficient water management contributes to market stability.
- The Monte Carlo simulation successfully modeled realistic fluctuations in corporate value influenced by both environmental and market conditions.

- Integration of environmental datasets with company-level data provided a holistic understanding of sustainability-driven financial outcomes.
- The developed approach forms a scalable foundation for integrating future environmental, social, and governance (ESG) metrics into AI-driven economic modeling.

8.2 Limitations

Despite its successful implementation, the system is subject to certain limitations:

- The simulation relies on simplified water footprint data and estimated sales figures, which may not fully reflect real-world variability.
- External market factors such as inflation, political conditions, and investor sentiment were not explicitly modeled.
- The Luck Factor (ϵ) is randomly generated, making the simulation non-deterministic and dependent on statistical approximations.

8.3 Applications

The proposed system can be extended and adapted to several real-world applications that bridge sustainability analytics with market intelligence:

- **Stock Prediction:** Financial analysts and organizations can use sustainability-weighted Monte Carlo simulations to forecast stock performance, enabling predictions that factor in environmental and industrial risks. This application supports eco-conscious investment decisions aligned with global ESG standards.
- **Stock Management:** Intermediate financial institutions and brokerage firms can utilize this model to design adaptive portfolio management systems that monitor stock health in relation to sustainability parameters such as water footprint, carbon intensity, and industrial efficiency.
- **Stock Production / Handling Platforms:** FinTech and AI-based trading platforms can integrate this approach to automate buying or selling decisions based on dynamic sustainability indices. Such systems could help regulate stock flows in markets prioritizing green and responsible investments.

By applying this framework across various industries, companies and investors can shift toward more sustainable decision-making — aligning profitability with environmental accountability.

8.4 Future Scope

The potential future extensions of this work open exciting avenues for both research and industry applications:

- **Integration with Real-Time Financial APIs:** Linking live market data to continuously update simulation parameters.
- **Incorporation of ESG Ratings:** Extending the model to include environmental, social, and governance scores for deeper sustainability insights.
- **Machine Learning Enhancement:** Using reinforcement or deep learning models to predict optimal sustainability strategies for companies.
- **Geospatial Water Risk Modeling:** Employing satellite or remote sensing data to dynamically monitor country-level water stress indicators.
- **Portfolio Risk Assessment:** Applying the model for multi-company portfolio simulation to assess sector-wide sustainability impacts.

In conclusion, this work demonstrates how the synergy of **statistical simulation, AI reasoning, and environmental analytics** can reshape modern financial decision-making. The **Water Sustainability Index–driven Monte Carlo framework** is not only a predictive model but also a forward-looking decision-support system. As sustainability continues to become a key determinant of corporate value, such hybrid models will play an increasingly vital role in aligning global finance with environmental responsibility.

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