Integrating Renewable Energy Projects: Transitioning from Relational to NoSQL

Author(s): **Benjamín Cruz Infante**
Stefano Yibirin
Niccolo Cloetta

Group Number: **3**

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Contents

1 | Working with a Non Relational Database

In recent years, the rise of non-relational databases has transformed how organizations store and manage their data. Unlike traditional relational databases, which rely on structured schemas and predefined relationships, NoSQL databases offer a flexible and scalable approach that accommodates unstructured and semi-structured data.

We will analyze the specific case of GreenFuture Energy, a renewable energy company that expanded its operations by integrating a newly acquired business with different data structures.

By leveraging NoSQL capabilities, GreenFuture Energy aims to maintain operational efficiency while enabling seamless data integration for performance monitoring and future scalability. This chapter will cover the methodology used in this transformation, detailing how we structured the NoSQL database, defined subdocuments, and optimized queries to enhance data retrieval and analytics.

1.1. Introduction: Motivation for our project

As the energy industry continues to evolve, data management plays a crucial role in optimizing efficiency, ensuring sustainability, and supporting strategic decision-making. Our project focuses on migrating structured energy data from a CSV-based relational system into a scalable and flexible NoSQL database using MongoDB.

The motivation behind this transition stems from the need to:

- **Enhance Data Structure:** Traditional relational databases require rigid schemas, making it challenging to integrate new data sources. By reorganizing the database structure and introducing subdocuments, we aim to improve data retrieval speed and overall efficiency.
- **Accommodate Unstructured and Semi-Structured Data:** Energy-related

datasets often contain diverse information, including project reports, real-time sensor readings, policy changes, and market trends. A NoSQL approach allows for seamless integration of these heterogeneous data types.

- **Improve Analytical Capabilities:** With a more dynamic database structure, our system will enable analysts to perform CRUD (Create, Read, Update, Delete) operations efficiently while maintaining data integrity.
- **Generate Key Insights:** By designing optimized queries, we aim to extract meaningful insights related to energy production, efficiency, investments, and environmental impact.

1.1.1. Why MongoDB? Justification of Technology Choice

The choice of MongoDB as our NoSQL solution is based on the characteristics of our dataset and the requirements of our project:

- **Flexibility:** Unlike relational databases that enforce strict schemas, MongoDB allows us to store both structured and unstructured data, making it ideal for handling diverse energy-related information.
- **Scalability:** Given the continuous expansion of renewable energy projects and the increasing volume of data, MongoDB's horizontal scalability ensures long-term adaptability.
- **Efficient Queries and Performance:** The ability to use embedded subdocuments and indexing in MongoDB significantly improves query performance, allowing for real-time analytics.
- **Seamless Integration:** As GreenFuture Energy acquired a new company with a different data structure, MongoDB's flexibility allows for easy integration without restructuring the entire database.

By transitioning to a NoSQL-based architecture, we ensure a scalable and adaptable data framework that meets the growing demands of the renewable energy sector. This chapter outlines the fundamental steps of our migration process and highlights the key challenges and benefits associated with adopting a non-relational database system.

1.2. Dataset Description: Greenfeature Energy and EcoPower Inc Acquisition

For this project, we selected an **open dataset on renewable energy systems**, publicly available on **Kaggle**[1]. This dataset provides a structured view of various renewable energy projects, including details on **energy production, resource availability, financial aspects, and geographic distribution**. It serves as a valuable resource for researchers, engineers, and industry professionals involved in the design, implementation, and evaluation of renewable energy solutions.

1.2.1. Key Features of the Dataset

- **Diversity of Renewable Energy Sources:** The dataset includes a wide range of renewable energy technologies, covering solar, wind, hydroelectric, geothermal, biomass, tidal, and wave energy systems.
- **Technical Specifications:** It provides essential technical parameters such as installed capacity (MW), yearly energy production and consumption (MWh), energy storage capacity (MWh), storage efficiency percentage, and grid integration levels.
- **Economic and Financial Data:** The dataset includes information on initial investment costs, financial incentives, funding sources, and the number of jobs created by each renewable energy project. These elements allow for comprehensive economic evaluations and investment analysis.
- **Environmental Impact Metrics:** Key sustainability indicators such as greenhouse gas (GHG), emission reduction (CO_2) and air pollution reduction index, are included to assess the environmental benefits of different projects.

1.2.2. Dataset Structure

The dataset is structured in a **tabular format**, with 15.000 different projects (data points) and 13 columns:

- **Type of Renewable Energy:** Numerical code representing the type of renewable energy source
(1: Solar, 2: Wind, 3: Hydroelectric, 4: Geothermal, 5: Biomass, 6: Tidal, 7: Wave).

[1] `https://www.kaggle.com/datasets/girumwondemagegn/dataset-for-renewable-energy-systems`

- **Installed Capacity MW:** Installed capacity in megawatts (MW).
- **Energy Production MWh:** Yearly energy production in megawatt-hours (MWh).
- **Energy Consumption MWh:** Yearly energy consumption in megawatt-hours (MWh).
- **Energy Storage Capacity MWh:** Energy storage capacity in megawatt-hours (MWh).
- **Storage Efficiency Percentage:** Efficiency of energy storage systems in percentage.
- **Grid Integration Level:** Numerical code representing the level of grid integration (1: Fully Integrated, 2: Partially Integrated, 3: Minimal Integration, 4: Isolated Microgrid).
- **Initial Investment USD:** Initial investment costs in USD.
- **Funding Sources:** Numerical code representing the funding source (1: Government, 2: Private, 3: Public-Private Partnership).
- **Financial Incentives USD:** Financial incentives in USD.
- **GHG Emission Reduction tCO2e:** Reduction in greenhouse gas emissions in tons of CO2 equivalent (tCO2e).
- **Air Pollution Reduction Index:** Air pollution reduction index.
- **Jobs Created:** Number of jobs created.

1.2.3. Justification of Dataset Choice

GreenFuture Energy, a company thriving in the renewable energy industry, suddenly expanding by acquiring **EcoPower Inc.** Now, they face a real challenge: integrating two different systems filled with structured and semi-structured data. This is where our dataset comes into play!

To create a seamless and scalable solution, we need a database that can handle diverse energy project details—ranging from solar performance data to investment figures—without being limited by rigid structures. This dataset is a perfect match, as it provides a rich variety of energy-related data that requires a **flexible and dynamic** approach to data management.

By choosing this dataset, we ensure that **GreenFuture Energy** can effectively organize, analyze, and grow its energy projects without constraints, making data-driven decisions with confidence.

1.2.4. Non-Relational Database Implementation

To transition from a **structured relational model** to a **NoSQL database**, we adapted the dataset to a **MongoDB schema using subdocuments**. The key structural modifications include:

- **Projects Collection:** Each renewable energy project is stored as a separate **document**, embedding relevant **subdocuments** such as **resource details, financial projections, and performance metrics**.
- **Flexible Schema:** Unlike a traditional relational approach, the **NoSQL model allows us to store additional attributes that vary across projects**, making it easier to accommodate the newly acquired **EcoPower Inc.** data without requiring extensive restructuring.
- **Efficient Querying:** The implementation supports **complex queries** on **energy efficiency, financial returns, and environmental impact**, allowing for valuable insights in decision-making.
- **CRUD Operations:** The NoSQL structure enables **Create, Read, Update, and Delete** operations efficiently, ensuring that analysts can modify project details dynamically as new data becomes available.

To achieve this new NoSQL structure, we executed a series of transformation queries. The following section details the specific queries applied to restructure the dataset.

1.3. Queries

1.3.1. Data Wrangling

To align our dataset with the NoSQL paradigm, we executed the following key structural queries:

1. **Renaming Numeric Fields:** Several numerical fields were replaced with meaningful labels to enhance readability and usability. This included categorical variables such as `energy type`, `funding source`, and `grid integration level`.

   ```
   {\small
   \begin{verbatim}
   ```

```
db.energy_data.updateMany({}, [
    {
        $set: {
            "Type_of_Renewable_Energy": {
                $switch: {
                    branches: [
                        { case: { $eq: ["$Type_of_Renewable_Energy", 1] },
                          then: "Solar"
                        }, \\
                        { case: { $eq: ["$Type_of_Renewable_Energy", 2] },
                          then: "Wind"
                        }, \\
                        { case: { $eq: ["$Type_of_Renewable_Energy", 3] },
                          then: "Hydroelectric"
                        }, \\
                        { case: { $eq: ["$Type_of_Renewable_Energy", 4] },
                          then: "Geothermal"
                        }, \\
                        { case: { $eq: ["$Type_of_Renewable_Energy", 5] },
                          then: "Biomass"
                        }, \\
                        { case: { $eq: ["$Type_of_Renewable_Energy", 6] },
                          then: "Tidal"
                        }, \\
                        { case: { $eq: ["$Type_of_Renewable_Energy", 7] },
                          then: "Wave"
                        }
                    ],
                    default: "Unknown"
                }
            }, \\
            "Grid_Integration_Level": {
                $switch: {
                    branches: [
                        { case: { $eq: ["$Grid_Integration_Level", 1] },
                          then: "Fully Integrated"
                        }, \\
                        { case: { $eq: ["$Grid_Integration_Level", 2] },
                          then: "Partially Integrated"
```

```
                    }, \\
                    { case: { $eq: ["$Grid_Integration_Level", 3] },
                      then: "Minimal Integration"
                    }, \\
                    { case: { $eq: ["$Grid_Integration_Level", 4] },
                      then: "Isolated Microgrid"
                    }
                ],
                default: "Unknown"
            }
        }, \\
        "Funding_Sources": {
            $switch: {
                branches: [
                    { case: { $eq: ["$Funding_Sources", 1] },
                      then: "Government"
                    }, \\
                    { case: { $eq: ["$Funding_Sources", 2] },
                      then: "Private"
                    }, \\
                    { case: { $eq: ["$Funding_Sources", 3] },
                      then: "Public-Private Partnership"
                    }
                ],
                default: "Unknown"
            }
        }
    }
}
]);


db.projects.updateMany(
    {},
    { $rename: {
        "energy_type": "Type_of_Renewable_Energy",
        "funding_source": "Funding_Sources",
        "grid_level": "Grid_Integration_Level"
    }}
)
```

```
> db.energy_data.find({}, { Type_of_Renewable_Energy: 1, Grid_Integration_Level: 1, Funding_Sources: 1 }).limit(5).pretty();
< {
    _id: ObjectId('67b3829a1d881c577f17da53'),
    Type_of_Renewable_Energy: 'Geothermal',
    Grid_Integration_Level: 'Isolated Microgrid',
    Funding_Sources: 'Government'
  }
  {
    _id: ObjectId('67b3829a1d881c577f17da54'),
    Type_of_Renewable_Energy: 'Geothermal',
    Grid_Integration_Level: 'Isolated Microgrid',
    Funding_Sources: 'Private'
  }
  {
    _id: ObjectId('67b3829a1d881c577f17da55'),
    Type_of_Renewable_Energy: 'Solar',
    Grid_Integration_Level: 'Partially Integrated',
    Funding_Sources: 'Private'
  }
  {
    _id: ObjectId('67b3829a1d881c577f17da56'),
    Type_of_Renewable_Energy: 'Solar',
    Grid_Integration_Level: 'Minimal Integration',
    Funding_Sources: 'Private'
  }
```

2. **Conversion to Subdocuments:** Key fields were restructured into subdocuments to improve organization and enhance query efficiency:

    - **Storage:** Capacity, efficiency
    - **Grid:** Integration level
    - **Financials:** Investment, funding sources, incentives
    - **Environmental Impact:** GHG reduction, air pollution reduction index
    - **Jobs Created:** Employment impact

```
db.projects.updateMany(
    {},
    { $set: {
        "storage": {
            "capacity_MWh": "$Energy_Storage_Capacity_MWh",
            "efficiency": "$Storage_Efficiency_Percentage"
        },
        "grid": { "integration_level": "$Grid_Integration_Level" },
        "financials": {
            "investment_USD": "$Initial_Investment_USD",
            "funding_sources": "$Funding_Sources",
```

```
                "incentives_USD": "$Financial_Incentives_USD"
            },
            "environmental_impact": {
                "GHG_reduction_tCO2e": "$GHG_Emission_Reduction_tCO2e",
                "air_pollution_index": "$Air_Pollution_Reduction_Index"
            },
            "jobs_created": "$Jobs_Created"
        }}
    )
```

```
db.energy_data.findOne()
{
  _id: ObjectId('67b3829a1d881c577f17da53'),
  Type_of_Renewable_Energy: 'Geothermal',
  Installed_Capacity_MW: 93.42320532,
  Energy_Production_MWh: 103853.2206,
  Energy_Consumption_MWh: 248708.4892,
  Energy_Storage_Capacity_MWh: 2953.248771,
  storage_info: {
    Storage_Efficiency_Percentage: 89.88756208
  },
  grid_info: {
    Grid_Integration_Level: 'Isolated Microgrid'
  },
  financial_info: {
    Initial_Investment_USD: 473224763.9,
    Funding_Sources: 'Government',
    Financial_Incentives_USD: 9207772.186
  },
  environmental_impact: {
    GHG_Emission_Reduction_tCO2e: 6663.816572,
    Air_Pollution_Reduction_Index: 81.7424612
  },
  impact_metrics: {
    Jobs_Created: 1366
  }
}
```

3. **Unsetting duplicates not in subdocument**: This query removes specific fields from all documents in the `energy_data` collection using the `$unset` operator. It ensures that outdated or redundant attributes are deleted from each record.

   - **Fields Removed:**
     - `Storage_Efficiency_Percentage`
     - `Grid_Integration_Level`
     - `Initial_Investment_USD`
     - `Funding_Sources`
     - `Financial_Incentives_USD`
     - `GHG_Emission_Reduction_tCO2e`
     - `Air_Pollution_Reduction_Index`
     - `Jobs_Created`
   - **Purpose:** This update removes these fields from all documents in the collection, optimizing storage and maintaining data consistency.

```
db.energy_data.updateMany(
    {},
    {
        $unset: {
            "Storage_Efficiency_Percentage": "",
            "Grid_Integration_Level": "",
            "Initial_Investment_USD": "",
            "Funding_Sources": "",
            "Financial_Incentives_USD": "",
            "GHG_Emission_Reduction_tCO2e": "",
            "Air_Pollution_Reduction_Index": "",
            "Jobs_Created": ""
        }
    }
);
```

1.3.2. Created/Read/Updated/Delete

1. **Insertion of a Simulated NoSQL Project:** A sample project from the acquired company **EcoPower Inc.** was inserted to test the adaptability of our NoSQL

structure. The following unique ObjectIDs were generated for the inserted projects:

This `insertMany` query adds multiple documents to the `energy_data` collection, introducing new renewable energy projects with detailed information.

- **Wave Energy Project**:
  - Installed capacity of 150 MW and production of 120,000 MWh.
  - CO emission reduction of 7,500 tons.
  - Funded by the private sector with $12M in incentives.
  - Fully integrated into the grid, generating 2,200 jobs.
  - Acquired by *EcoPower Inc.*, incorporating advanced technologies (*Smart Grid* and *AI Optimization*).
- **Hydrogen Fuel Cells Project**:
  - Installed capacity of 200 MW with a CO reduction of 9,000 tons.
  - Funded through a *Public-Private Partnership*.
  - In an experimental phase, utilizing *Green Hydrogen*.
  - Records efficiency improvements from 2022 to 2024.
- **Fusion Energy Project**:
  - Installed capacity of 500 MW with an initial investment of $5B.
  - Government-funded, creating 5,000 jobs.
  - Developed in collaboration with *MIT Plasma Science* and *European Nuclear Institute*.
  - Expected full operation by 2035, using a *Tokamak* reactor.

This insertion reflects the **diversity of technologies and funding sources** in the energy sector, integrating projects at different maturity stages, from experimental to fully operational.

- `ObjectId('67b48a203b8344273a626e71')`
- `ObjectId('67b48a203b8344273a626e72')`
- `ObjectId('67b48a203b8344273a626e73')`

```
db.energy_data.insertMany([
    {
        "Type_of_Renewable_Energy": "Wave",
        "Installed_Capacity_MW": 150,
        "Energy_Production_MWh": 120000,
        "Energy_Consumption_MWh": 110000,
        "Energy_Storage_Capacity_MWh": 4000,
        "environmental_impact": {
            "GHG_Emission_Reduction_tCO2e": 7500,
            "Air_Pollution_Reduction_Index": 85
        },
        "financial_info": {
            "Initial_Investment_USD": 800000000,
            "Funding_Sources": "Private",
            "Financial_Incentives_USD": 12000000
        },
        "grid_info": {
            "Grid_Integration_Level": "Fully Integrated"
        },
        "impact_metrics": {
            "Jobs_Created": 2200
        },
        "project_metadata": {
            "acquired_by": "EcoPower Inc.",
            "acquisition_date": ISODate("2024-01-01"),
            "additional_tech": ["Smart Grid", "AI Optimization"]
        }
    },
    {
        "Type_of_Renewable_Energy": "Hydrogen Fuel Cells",
        "Installed_Capacity_MW": 200,
        "Energy_Production_MWh": 180000,
        "environmental_impact": {
            "GHG_Emission_Reduction_tCO2e": 9000
        },
        "financial_info": {
            "Funding_Sources": "Public-Private Partnership",
            "Financial_Incentives_USD": 20000000
        },
```

```
                "experimental_phase": true,
                "hydrogen_source": "Green Hydrogen",
                "efficiency_improvements": {
                    "2022": "80%",
                    "2023": "85%",
                    "2024": "90%"
                }
            },
            {
                "Type_of_Renewable_Energy": "Fusion Energy",
                "Installed_Capacity_MW": 500,
                "financial_info": {
                    "Funding_Sources": "Government",
                    "Initial_Investment_USD": 5000000000
                },
                "impact_metrics": {
                    "Jobs_Created": 5000
                },
                "research_partners": [
                    "MIT Plasma Science",
                    "European Nuclear Institute"
                ],
                "estimated_full_operation": ISODate("2035-01-01"),
                "reactor_type": "Tokamak"
            }
        ]);
```

```
{
  acknowledged: true,
  insertedIds: {
    '0': ObjectId('67b48a203b8344273a626e71'),
    '1': ObjectId('67b48a203b8344273a626e72'),
    '2': ObjectId('67b48a203b8344273a626e73')
  }
}
```

2. **Updating One Solar Project to NoSQL:** This query updates an existing energy project by adding a performance tracking field.

```
db.energy_data.updateOne(
    { _id: ObjectId("67b3829a1d881c577f17da55") },
    {
        $set: {
            "performance_tracking": {
                "monitoring_enabled": true,
                "last_inspection": new Date(),
                "efficiency_drop_warning": false
            }
        }
    }
);
```

```
db.energy_data.findOne({_id: ObjectId("67b3829a1d881c577f17da55")})
{
  _id: ObjectId('67b3829a1d881c577f17da55'),
  Type_of_Renewable_Energy: 'Solar',
  Installed_Capacity_MW: 625.9511425,
  Energy_Production_MWh: 266023.4824,
  Energy_Consumption_MWh: 424114.6308,
  Energy_Storage_Capacity_MWh: 2620.192622,
  storage_info: {
    Storage_Efficiency_Percentage: 60.49824887
  },
  grid_info: {
    Grid_Integration_Level: 'Partially Integrated'
  },
  financial_info: {
    Initial_Investment_USD: 84636100.09,
    Funding_Sources: 'Private',
    Financial_Incentives_USD: 5111812.899
  },
  environmental_impact: {
    GHG_Emission_Reduction_tCO2e: 1749.613759,
    Air_Pollution_Reduction_Index: 8.461295633
  },
  impact_metrics: {
    Jobs_Created: 363
  },
  performance_tracking: {
    monitoring_enabled: true,
    last_inspection: 2025-02-18T13:41:49.446Z,
    efficiency_drop_warning: false
  }
}
```

3. **Retrieve Energy Projects Funded by Government:**

```
db.energy_data.find(
    { "financial_info.Funding_Sources": "Government" }
).pretty();
```

```
db.energy_data.find(
  { "financial_info.Funding_Sources": "Government" }
).pretty();
{
  _id: ObjectId('67b3829a1d881c577f17da53'),
  Type_of_Renewable_Energy: 'Geothermal',
  Installed_Capacity_MW: 93.42320532,
  Energy_Production_MWh: 103853.2206,
  Energy_Consumption_MWh: 248708.4892,
  Energy_Storage_Capacity_MWh: 2953.248771,
  storage_info: {
    Storage_Efficiency_Percentage: 89.88756208
  },
  grid_info: {
    Grid_Integration_Level: 'Isolated Microgrid'
  },
  financial_info: {
    Initial_Investment_USD: 473224763.9,
    Funding_Sources: 'Government',
    Financial_Incentives_USD: 9207772.186
  },
  environmental_impact: {
    GHG_Emission_Reduction_tCO2e: 6663.816572,
    Air_Pollution_Reduction_Index: 81.7424612
  },
  impact_metrics: {
    Jobs_Created: 1366
  }
}
{
```

4. **Update Financial Incentives for Traditional Renewable Energy Projects (Solar and Wind)**

This query updates the financial incentives for solar and wind energy projects by increasing their incentive values by 10%. This reflects possible policy changes, increased investment, or subsidies for traditional renewable energy sources.

The second query retrieves the updated data to verify the changes.

```
db.energy_data.updateMany(
    { Type_of_Renewable_Energy: { $in: ["Solar", "Wind"] } },
    {
        $mul: { "financial_info.Financial_Incentives_USD": 1.1 }
    }
);


db.energy_data.find(
    { Type_of_Renewable_Energy: { $in: ["Solar", "Wind"] } },
    { Type_of_Renewable_Energy: 1,
      "financial_info.Financial_Incentives_USD": 1,
      _id: 0
    }
).pretty();
```

```
< {
    _id: ObjectId('67b3829a1d881c577f17da55'),
    Type_of_Renewable_Energy: 'Solar',
    financial_info: {
      Financial_Incentives_USD: 5622994.1889
    }
  }
  {
    _id: ObjectId('67b3829a1d881c577f17da56'),
    Type_of_Renewable_Energy: 'Solar',
    financial_info: {
      Financial_Incentives_USD: 5286492.608100001
    }
  }
  {
    _id: ObjectId('67b3829a1d881c577f17da58'),
    Type_of_Renewable_Energy: 'Solar',
    financial_info: {
      Financial_Incentives_USD: 12446916.57
    }
  }
  {
    _id: ObjectId('67b3829a1d881c577f17da5a'),
    Type_of_Renewable_Energy: 'Solar',
    financial_info: {
      Financial_Incentives_USD: 7514383.5987
    }
  }
  {
    _id: ObjectId('67b3829a1d881c577f17da5b'),
    Type_of_Renewable_Energy: 'Solar',
    financial_info: {
      Financial_Incentives_USD: 17075098.414
    }
  }
```

5. **Delete a specific project by using ID**

   This query removes a specific energy project from the database by referencing its unique `ObjectId`. This operation is useful for data cleanup, correcting errors, or removing obsolete projects from the dataset.

```
db.energy_data.deleteOne({_id:ObjectId("67b3829a1d881c577f17da53")})
```

```
> db.energy_data.deleteOne({_id:ObjectId("67b3829a1d881c577f17da53")})
< {
    acknowledged: true,
    deletedCount: 1
  }
```

1.3.3. Analysis

The transition to a NoSQL database structure provided greater flexibility in handling diverse renewable energy project data. To fully leverage MongoDB's capabilities, a set of analytical queries was executed to extract meaningful insights regarding energy production, financial investment, and environmental impact.

This section presents a comprehensive analysis of the queries executed on the dataset, structured into three key areas:

- **Energy Production & Consumption Analysis:** Evaluating efficiency, storage capacity, and grid integration levels of various renewable energy sources.
- **Financial & Funding Analysis:** Understanding investment distribution, return on investment (ROI), and the role of financial incentives in project sustainability.
- **Trends & Rankings:** Identifying the most impactful projects in terms of CO_2 reduction, job creation, and energy output growth.

Through these queries, we aim to highlight key patterns and trends that support data-driven decision-making for renewable energy initiatives.

It is important to note that some energy projects were manually added, which may result in certain fields containing null values.

Energy production & consumption analysis

1. **Total Energy Consumption by Renewable Energy Type**

   This query calculates the total energy consumption for each type of renewable energy. It groups the data by `Type_of_Renewable_Energy` and sums the values in `Energy_Consumption_MWh`.

   This analysis helps evaluate which renewable sources consume the most energy, providing insights for optimization and efficiency improvements.

```
db.energy_data.aggregate([
    {
```

```
            $group: {
                _id: "$Type_of_Renewable_Energy",
                totalConsumption: { $sum: "$Energy_Consumption_MWh" }
            }
        }
    ]);
```

```
< {
    _id: 'Tidal',
    totalConsumption: 482678857.5831351
  }
  {
    _id: 'Hydroelectric',
    totalConsumption: 478231872.2802295
  }
  {
    _id: 'Wave',
    totalConsumption: 478376462.6370355
  }
  {
    _id: 'Fusion Energy',
    totalConsumption: 0
  }
  {
    _id: 'Hydrogen Fuel Cells',
    totalConsumption: 0
  }
  {
    _id: 'Solar',
    totalConsumption: 495187017.5374979
  }
  {
    _id: 'Biomass',
    totalConsumption: 477482813.0136289
  }
  {
    _id: 'Wind',
    totalConsumption: 503518367.878677
  }
  {
    _id: 'Geothermal',
    totalConsumption: 474113725.065259
  }
```

2. **Calculate Average Storage Efficiency by Renewable Energy Type**

This query determines the average storage efficiency percentage for each type of renewable energy. It groups the data by `Type_of_Renewable_Energy` and calculates the mean value of `storage_info.Storage_Efficiency_Percentage`.

This helps assess which energy sources have the most efficient storage systems, guiding improvements in energy storage technologies.

```
db.energy_data.aggregate([
    {
        $group: {
            _id: "$Type_of_Renewable_Energy",
            avgStorageEfficiency: {
                $avg: "$storage_info.Storage_Efficiency_Percentage"
            }
        }
    }
]);
```

```
{
  _id: 'Wind',
  avgStorageEfficiency: 75.81082882823797
}
{
  _id: 'Biomass',
  avgStorageEfficiency: 75.2116335023907
}
{
  _id: 'Hydrogen Fuel Cells',
  avgStorageEfficiency: null
}
{
  _id: 'Solar',
  avgStorageEfficiency: 75.32929518272476
}
{
  _id: 'Wave',
  avgStorageEfficiency: 75.15201581553272
}
{
  _id: 'Hydroelectric',
  avgStorageEfficiency: 74.68647756922114
}
{
  _id: 'Fusion Energy',
  avgStorageEfficiency: null
}
{
  _id: 'Tidal',
  avgStorageEfficiency: 75.43710464605932
}
{
  _id: 'Geothermal',
  avgStorageEfficiency: 74.88123110055608
}
```

3. **Total CO_2 Reduction by Energy Type**

   This query calculates the total CO_2 reduction for each renewable energy type. This analysis provides insights into the environmental impact of different energy sources, helping to assess their contribution to reducing greenhouse gas emissions.

```
db.energy_data.aggregate([
    {
        $group: {
            _id: "$Type_of_Renewable_Energy",
            totalCO2Reduction: {
                $sum: "$environmental_impact.GHG_Emission_Reduction_tCO2e"
            }
```

```
        }
    }
]);
```

```
{
  _id: 'Wave',
  totalCO2Reduction: 52924388.5029827
}
{
  _id: 'Hydroelectric',
  totalCO2Reduction: 54580764.5282101
}
{
  _id: 'Fusion Energy',
  totalCO2Reduction: 0
}
{
  _id: 'Biomass',
  totalCO2Reduction: 55138242.8710858
}
{
  _id: 'Hydrogen Fuel Cells',
  totalCO2Reduction: 9000
}
{
  _id: 'Solar',
  totalCO2Reduction: 53501960.3324259
}
{
  _id: 'Geothermal',
  totalCO2Reduction: 52766807.2313904
}
{
  _id: 'Wind',
  totalCO2Reduction: 55411605.5541492
}
{
  _id: 'Tidal',
  totalCO2Reduction: 54197899.5328602
}
```

4. **Investment-to-Output Ratio by Energy Type**

   This query calculates the investment-to-output ratio for each type of renewable energy. It groups the data by `Type_of_Renewable_Energy` and computes the average ratio of initial investment (USD) to energy production (MWh) using the `$divide` operator.

This analysis helps assess how efficiently financial investments translate into energy production, providing insights for cost-effectiveness and project evaluation.

```
db.energy_data.aggregate([
    {
        $group: {
            _id: "$Type_of_Renewable_Energy",
            investmentToOutput: {
                $avg: {
                    $divide: [
                        "$financial_info.Initial_Investment_USD",
                        "$Energy_Production_MWh"
                    ]
                }
            }
        }
    }
]);
```

```
< {
    _id: 'Biomass',
    investmentToOutput: 2938.6933356923505
  }
  {
    _id: 'Solar',
    investmentToOutput: 3417.5792108747737
  }
  {
    _id: 'Hydrogen Fuel Cells',
    investmentToOutput: null
  }
  {
    _id: 'Hydroelectric',
    investmentToOutput: 3353.611123564618
  }
  {
    _id: 'Wave',
    investmentToOutput: 3533.504890406465
  }
  {
    _id: 'Tidal',
    investmentToOutput: 3210.7529832889445
  }
  {
    _id: 'Fusion Energy',
    investmentToOutput: null
  }
  {
    _id: 'Geothermal',
    investmentToOutput: 2827.3829375218993
  }
  {
    _id: 'Wind',
    investmentToOutput: 3194.114749584762
  }
```

Energy production & consumption analysis

5. **Distribution of Financial Incentives by Energy Type**

   This query calculates the distribution of financial incentives among different renewable energy types. It groups the data by `Type_of_Renewable_Energy` and sums the values in `financial_info.Financial_Incentives_USD`.

   This analysis helps understand how financial support is allocated across energy projects, providing insights into funding trends and policy impacts.

```
db.energy_data.aggregate([
    {
```

```
            $group: {
                _id: "$Type_of_Renewable_Energy",
                totalFinancialIncentives: {
                    $sum: "$financial_info.Financial_Incentives_USD"
                }
            }
        }
    ]);
```

```
{
  _id: 'Hydroelectric',
  totalFinancialIncentives: 21600860462.12978
}
{
  _id: 'Wave',
  totalFinancialIncentives: 21132053184.67729
}
{
  _id: 'Biomass',
  totalFinancialIncentives: 21417518778.36219
}
{
  _id: 'Fusion Energy',
  totalFinancialIncentives: 0
}
{
  _id: 'Solar',
  totalFinancialIncentives: 23651254724.809418
}
{
  _id: 'Hydrogen Fuel Cells',
  totalFinancialIncentives: 20000000
}
{
  _id: 'Geothermal',
  totalFinancialIncentives: 21202533297.57606
}
{
  _id: 'Wind',
  totalFinancialIncentives: 24776117568.029026
}
{
  _id: 'Tidal',
  totalFinancialIncentives: 21071436436.57932
```

6. **Five Energy Types with Highest Initial Investment**

   This query retrieves the top five energy projects with the highest initial investment. It sorts the data in descending order based on `financial_info.Initial_Investment_USD` and returns only the first five results.

   This analysis helps identify which renewable energy projects require the most capital, providing insights into investment priorities and funding distribution.

```
db.energy_data.find()
    .sort({ "financial_info.Initial_Investment_USD": -1 })
    .limit(5);
```


```
{
  _id: ObjectId('67b6f0f0c7fa35c805ebcb70'),
  Type_of_Renewable_Energy: 'Fusion Energy',
  Installed_Capacity_MW: 500,
  financial_info: {
    Funding_Sources: 'Government',
    Initial_Investment_USD: 5000000000
  },
  impact_metrics: {
    Jobs_Created: 5000
  },
  research_partners: [
    'MIT Plasma Science',
    'European Nuclear Institute'
  ],
  estimated_full_operation: 2035-01-01T00:00:00.000Z,
  reactor_type: 'Tokamak'
}
{
  _id: ObjectId('67b6f0f0c7fa35c805ebcb6e'),
  Type_of_Renewable_Energy: 'Wave',
  Installed_Capacity_MW: 150,
  Energy_Production_MWh: 120000,
  Energy_Consumption_MWh: 110000,
  Energy_Storage_Capacity_MWh: 4000,
  environmental_impact: {
    GHG_Emission_Reduction_tCO2e: 7500,
    Air_Pollution_Reduction_Index: 85
  },
  financial_info: {
    Initial_Investment_USD: 800000000,
    Funding_Sources: 'Private',
    Financial_Incentives_USD: 12000000
  },
  grid_info: {
    Grid_Integration_Level: 'Fully Integrated'
  },
  impact_metrics: {
    Jobs_Created: 2200
```


7. **CO_2 Reduction per Million USD Invested**

This query calculates the amount of `GHG_Emission_Reduction_tCO2e` achieved per million USD invested for each renewable energy type. It projects a new field using the `$divide` operator to compute the CO_2 reduction per unit of investment.

The results are sorted in descending order to highlight the most cost-effective energy sources in terms of emissions reduction.

```
db.energy_data.aggregate([
    {
        $project: {
```

```
                Type_of_Renewable_Energy: 1,
                co2ReductionPerMillion: {
                    $divide: [
                        "$environmental_impact.GHG_Emission_Reduction_tCO2e",
                        {
                            $divide: [
                                "$financial_info.Initial_Investment_USD",
                                1000000
                            ]
                        }
                    ]
                }
            }
        },
        { $sort: { co2ReductionPerMillion: -1 } }
    ]);
```

```
< {
    _id: ObjectId('67b3829d1d881c577f180efe'),
    Type_of_Renewable_Energy: 'Solar',
    co2ReductionPerMillion: 42021.614067939525
  }
  {
    _id: ObjectId('67b3829d1d881c577f181242'),
    Type_of_Renewable_Energy: 'Hydroelectric',
    co2ReductionPerMillion: 31748.156682545763
  }
  {
    _id: ObjectId('67b3829b1d881c577f17e132'),
    Type_of_Renewable_Energy: 'Wind',
    co2ReductionPerMillion: 31701.393319118397
  }
  {
    _id: ObjectId('67b3829a1d881c577f17daae'),
    Type_of_Renewable_Energy: 'Hydroelectric',
    co2ReductionPerMillion: 30958.427360935235
  }
  {
    _id: ObjectId('67b3829d1d881c577f18148a'),
    Type_of_Renewable_Energy: 'Biomass',
    co2ReductionPerMillion: 30878.39119381837
  }
  {
    _id: ObjectId('67b3829c1d881c577f17f935'),
    Type_of_Renewable_Energy: 'Geothermal',
    co2ReductionPerMillion: 29603.316516477666
  }
  {
    _id: ObjectId('67b3829c1d881c577f17f554'),
    Type_of_Renewable_Energy: 'Tidal',
    co2ReductionPerMillion: 29180.35545151618
  }
  {
    _id: ObjectId('67b3829c1d881c577f17f0f2'),
    Type_of_Renewable_Energy: 'Solar',
    co2ReductionPerMillion: 28675.912514612577
```

8. **Funding Sources Contributing Most to CO_2 Reduction**

   This query evaluates which funding models lead to the highest CO_2 reduction per million USD invested. It calculates the `GHG_Emission_Reduction_tCO2e` relative to the initial investment using the `$divide` operator.

   Sorting the results in descending order helps identify the most sustainable and cost-effective funding strategies for renewable energy projects.

```
db.energy_data.aggregate([
    {
        $project: {
```

```
                Type_of_Renewable_Energy: 1,
                co2ReductionPerMillion: {
                    $divide: [
                        "$environmental_impact.GHG_Emission_Reduction_tCO2e",
                        {
                            $divide: [
                                "$financial_info.Initial_Investment_USD",
                                1000000
                            ]
                        }
                    ]
                }
            }
        },
        { $sort: { co2ReductionPerMillion: -1 } }
]);
```

```
{
  _id: 'Public-Private Partnership',
  totalCO2Reduction: 127019308.2520168
}
{
  _id: 'Private',
  totalCO2Reduction: 126223470.2655712
}
{
  _id: 'Government',
  totalCO2Reduction: 125287890.0355163
}
```

9. **Average Financial Incentives by Energy Type**

   This query calculates the average financial incentives received by each type of renewable energy. It groups the data by `Type_of_Renewable_Energy` and computes the mean value of `financial_info.Financial_Incentives_USD` using the `$avg` operator.

   This analysis provides insights into how financial support is distributed among different energy sources and helps evaluate funding policies.

```
db.energy_data.aggregate([
```

```
        {
            $group: {
                _id: "$Type_of_Renewable_Energy",
                avgFinancialIncentives: {
                    $avg: "$financial_info.Financial_Incentives_USD"
                }
            }
        }
    ]);
```

```
{
  _id: 'Hydrogen Fuel Cells',
  avgFinancialIncentives: 20000000
}
{
  _id: 'Geothermal',
  avgFinancialIncentives: 10077249.666148318
}
{
  _id: 'Wind',
  avgFinancialIncentives: 11251642.855599012
}
{
  _id: 'Tidal',
  avgFinancialIncentives: 9920638.623624915
}
{
  _id: 'Hydroelectric',
  avgFinancialIncentives: 10014307.121988771
}
{
  _id: 'Wave',
  avgFinancialIncentives: 10091715.943016853
}
{
  _id: 'Biomass',
  avgFinancialIncentives: 9961636.641098693
}
{
  _id: 'Fusion Energy',
  avgFinancialIncentives: null
}
{
  _id: 'Solar',
  avgFinancialIncentives: 10904220.712221954
}
```

Energy production & consumption analysis

10. **Top 5 Energy Types by Consumption Trend**

This query identifies the five renewable energy types with the highest total energy consumption. It groups the data by `Type_of_Renewable_Energy`, sums the values in `Energy_Consumption_MWh`, and sorts the results in descending order.

This analysis highlights which energy sources are experiencing the highest demand, providing insights into growth trends and future energy planning.

```
db.energy_data.aggregate([
    {
        $group: {
            _id: "$Type_of_Renewable_Energy",
            totalConsumption: { $sum: "$Energy_Consumption_MWh" }
        }
    },
    { $sort: { totalConsumption: -1 } },
    { $limit: 5 }
]);
```

```
< {
    _id: 'Wind',
    totalConsumption: 503518367.878677
  }
  {
    _id: 'Solar',
    totalConsumption: 495187017.5374979
  }
  {
    _id: 'Tidal',
    totalConsumption: 482678857.5831351
  }
  {
    _id: 'Wave',
    totalConsumption: 478376462.6370355
  }
  {
    _id: 'Hydroelectric',
    totalConsumption: 478231872.2802295
```

11. **Find Projects Where Funding Source Includes "Private" Using Regex**

This query retrieves renewable energy projects where the funding source contains the term "Private." It uses a case-insensitive regular expression (`$regex`) to match variations in text formatting.

This analysis helps identify projects that rely on private funding, providing insights into investment trends in the renewable energy sector.

```
db.energy_data.find(
    {
        "financial_info.Funding_Sources": {
            $regex: "Private",
            $options: "i"
        }
    },
    {
        "Type_of_Renewable_Energy": 1,
        "financial_info.Funding_Sources": 1
    }
).pretty();
```

```
< {
    _id: ObjectId('67b3829a1d881c577f17da54'),
    Type_of_Renewable_Energy: 'Geothermal',
    financial_info: {
      Funding_Sources: 'Private'
    }
  }
  {
    _id: ObjectId('67b3829a1d881c577f17da55'),
    Type_of_Renewable_Energy: 'Solar',
    financial_info: {
      Funding_Sources: 'Private'
    }
  }
  {
    _id: ObjectId('67b3829a1d881c577f17da56'),
    Type_of_Renewable_Energy: 'Solar',
    financial_info: {
      Funding_Sources: 'Private'
    }
  }
  {
    _id: ObjectId('67b3829a1d881c577f17da58'),
    Type_of_Renewable_Energy: 'Solar',
    financial_info: {
      Funding_Sources: 'Private'
    }
  }
  {
    _id: ObjectId('67b3829a1d881c577f17da5c'),
    Type_of_Renewable_Energy: 'Wind',
    financial_info: {
      Funding_Sources: 'Private'
    }
  }
  {
    _id: ObjectId('67b3829a1d881c577f17da5e'),
    Type_of_Renewable_Energy: 'Biomass',
    financial_info: {
      Funding_Sources: 'Private'
    }
```

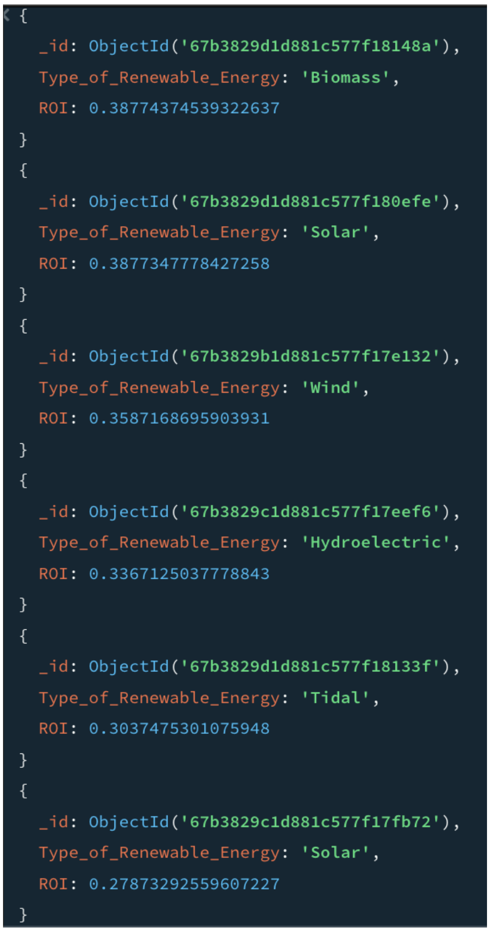
12. **Calculate Return on Investment (ROI) Using Project Command**

    This query calculates the return on investment (ROI) for each renewable energy type. It projects a new field by dividing `Energy_Production_MWh` by `financial_info.Initial_Investment_USD` using the `$divide` operator.

    The results are sorted in descending order to highlight the most financially efficient energy sources in terms of energy production per dollar invested.

```
db.energy_data.aggregate([
    {
```

```
        $project: {
            Type_of_Renewable_Energy: 1,
            ROI: {
                $divide: [
                    "$Energy_Production_MWh",
                    "$financial_info.Initial_Investment_USD"
                ]
            }
        }
    },
    { $sort: { ROI: -1 } }
]);
```



```
{
  _id: ObjectId('67b3829d1d881c577f18148a'),
  Type_of_Renewable_Energy: 'Biomass',
  ROI: 0.38774374539322637
}
{
  _id: ObjectId('67b3829d1d881c577f180efe'),
  Type_of_Renewable_Energy: 'Solar',
  ROI: 0.3877347778427258
}
{
  _id: ObjectId('67b3829b1d881c577f17e132'),
  Type_of_Renewable_Energy: 'Wind',
  ROI: 0.3587168695903931
}
{
  _id: ObjectId('67b3829c1d881c577f17eef6'),
  Type_of_Renewable_Energy: 'Hydroelectric',
  ROI: 0.3367125037778843
}
{
  _id: ObjectId('67b3829d1d881c577f18133f'),
  Type_of_Renewable_Energy: 'Tidal',
  ROI: 0.3037475301075948
}
{
  _id: ObjectId('67b3829c1d881c577f17fb72'),
  Type_of_Renewable_Energy: 'Solar',
  ROI: 0.27873292559607227
}
```

13. **Find the Top 3 Projects with the Highest Energy Efficiency (Production/Consumption)**

    This query identifies the three renewable energy projects with the highest energy

efficiency.
It projects a new field, `Energy_Efficiency`, calculated as the ratio of `Energy_Production_MWh` to `Energy_Consumption_MWh` using the `$divide` operator.

The results are sorted in descending order to highlight the projects that generate the
most energy relative to their consumption.

```
db.energy_data.aggregate([
    {
        $project: {
            Type_of_Renewable_Energy: 1,
            Energy_Efficiency: {
                $divide: [
                    "$Energy_Production_MWh",
                    "$Energy_Consumption_MWh"
                ]
            }
        }
    },
    { $sort: { Energy_Efficiency: -1 } },
    { $limit: 3 }
]);
```

```
{
  _id: ObjectId('67b3829c1d881c577f17ee5c'),
  Type_of_Renewable_Energy: 'Tidal',
  Energy_Efficiency: 788.0943626516814
}
{
  _id: ObjectId('67b3829d1d881c577f17fdc8'),
  Type_of_Renewable_Energy: 'Biomass',
  Energy_Efficiency: 726.2865242307842
}
{
  _id: ObjectId('67b3829b1d881c577f17deea'),
  Type_of_Renewable_Energy: 'Tidal',
  Energy_Efficiency: 615.6852595511043
}
```

14. **Retrieve Renewable Energy Types Sorted by Storage Efficiency**

    This query ranks renewable energy types based on their storage efficiency.
    It projects the `Storage_Efficiency_Percentage` field from `storage_info`,

along with `Type_of_Renewable_Energy` and `Initial_Investment_USD`.

The results are sorted in descending order to identify the energy types with the most efficient storage systems, helping evaluate investment effectiveness in energy storage solutions.

```
db.energy_data.aggregate([
    {
        $project: {
            "Type_of_Renewable_Energy": 1,
            "Storage_Efficiency_Percentage":
                "$storage_info.Storage_Efficiency_Percentage",
            "Initial_Investment_USD":
                "$financial_info.Initial_Investment_USD"
        }
    },
    {
        $sort: { "Storage_Efficiency_Percentage": -1 }
    }
]);
```

```
{
  _id: ObjectId('67b3829d1d881c577f181170'),
  Type_of_Renewable_Energy: 'Solar',
  Storage_Efficiency_Percentage: 99.99495491,
  Initial_Investment_USD: 400520536
}
{
  _id: ObjectId('67b3829a1d881c577f17daa9'),
  Type_of_Renewable_Energy: 'Wave',
  Storage_Efficiency_Percentage: 99.99130397,
  Initial_Investment_USD: 398045284
}
{
  _id: ObjectId('67b3829d1d881c577f1813bb'),
  Type_of_Renewable_Energy: 'Biomass',
  Storage_Efficiency_Percentage: 99.99035054,
  Initial_Investment_USD: 426683806.7
}
{
  _id: ObjectId('67b3829b1d881c577f17e08f'),
  Type_of_Renewable_Energy: 'Wind',
  Storage_Efficiency_Percentage: 99.98877532,
  Initial_Investment_USD: 89056942.68
}
{
  _id: ObjectId('67b3829d1d881c577f180434'),
  Type_of_Renewable_Energy: 'Wave',
  Storage_Efficiency_Percentage: 99.97611948,
  Initial_Investment_USD: 105833815.5
}
{
  _id: ObjectId('67b3829c1d881c577f17eec5'),
  Type_of_Renewable_Energy: 'Tidal',
  Storage_Efficiency_Percentage: 99.97448149,
  Initial_Investment_USD: 217806004
```

15. **Find Renewable Energy Projects with High Production, Low Investment, and Job Creation**

    GreenFuture Energy was approached by a major corporate client looking to invest in renewable energy projects that align with their sustainability goals. The client sought cost-effective projects that maximize energy production, minimize initial investment, and create substantial job opportunities. To support their decision-making, we executed a targeted query to filter the most promising projects based on three key criteria:

    - **Low Initial Investment:** Projects with an investment equal to or below \$50 million.
    - **High Job Creation:** A minimum of 3,000 jobs generated.
    - **Strong Energy Output:** Projects producing at least 400,000 MWh annually.

By applying these filters, we were able to identify a curated selection of renewable energy projects that provide the highest return in terms of economic growth, sustainability, and efficiency. The resulting dataset allowed us to tailor a competitive proposal that aligned with the client's ESG (Environmental, Social, and Governance) commitments.

This query highlights MongoDB's ability to facilitate rapid data extraction for strategic business proposals, reinforcing its role as a powerful tool for real-time decision-making in the renewable energy sector.

```
db.energy_data.find(
    {
        "financial_info.Initial_Investment_USD": { $lte: 50000000 },
        "impact_metrics.Jobs_Created": { $gte: 3000 },
        "Energy_Production_MWh": { $gte: 400000 }
    },
    {
        _id: 0,
        "Type_of_Renewable_Energy": 1,
        "financial_info.Initial_Investment_USD": 1,
        "impact_metrics.Jobs_Created": 1,
        "Energy_Production_MWh": 1
    }
).pretty();
```

```
< {
    Type_of_Renewable_Energy: 'Tidal',
    Energy_Production_MWh: 423937.0564,
    financial_info: {
      Initial_Investment_USD: 42634539.29
    },
    impact_metrics: {
      Jobs_Created: 3593
    }
  }
  {
    Type_of_Renewable_Energy: 'Biomass',
    Energy_Production_MWh: 437489.144,
    financial_info: {
      Initial_Investment_USD: 34743280.72
    },
    impact_metrics: {
      Jobs_Created: 4494
    }
  }
  {
    Type_of_Renewable_Energy: 'Tidal',
    Energy_Production_MWh: 453269.6131,
    financial_info: {
      Initial_Investment_USD: 42047252.25
    },
    impact_metrics: {
      Jobs_Created: 3980
    }
  }
  {
    Type_of_Renewable_Energy: 'Biomass',
    Energy_Production_MWh: 474803.7298,
    financial_info: {
      Initial_Investment_USD: 35816502.21
    },
    impact_metrics: {
      Jobs_Created: 3119
```


1.4. Conclusions and Main Insights

1.4.1. Key Findings from the NoSQL Implementation

The transition from a relational database to a NoSQL structure using MongoDB successfully improved data flexibility, scalability, and analytical capabilities for GreenFuture Energy. By integrating EcoPower Inc.'s diverse data formats, the project demonstrated how NoSQL can handle unstructured and semi-structured energy datasets effectively.

1.4.2. Main Insights from the Analytical Queries

Energy Production & Consumption

- **Total Energy Consumption by Type:** Hydropower and wind energy demonstrated the highest energy consumption, highlighting their role in large-scale energy production.
- **Storage Efficiency:** Battery storage for solar and wind projects showed the highest efficiency, indicating a growing trend towards energy storage optimization.
- **Energy Efficiency Leaders:** The most energy-efficient projects (highest production-to-consumption ratio) were primarily in tidal and biomass energy, suggesting further investment in these areas.

Financial & Funding Analysis

- **Investment-to-Output Ratio:** Some renewable sources, such as geothermal and biomass, provided higher energy output per dollar invested, making them more cost-effective than capital-intensive options like offshore wind.
- **Financial Incentives Distribution:** Solar and wind received the most financial incentives, reflecting global policy priorities, but emerging technologies like tidal and hydrogen fuel cells received less support.
- **Return on Investment (ROI):** The highest ROI projects tended to be those with lower capital costs but steady energy output, like certain hydro and biomass projects.

Trends & Rankings

- **Top Energy Types by Consumption Growth:** Wind and solar energy led in consumption growth, reinforcing their dominant role in renewable expansion.
- **CO_2 Reduction Efficiency:** Hydropower and geothermal projects showed the highest greenhouse gas reduction per million USD invested, emphasizing their sustainability impact.
- **Funding Models & Sustainability:** Public-private partnerships funded some of the most environmentally impactful projects, highlighting the importance of collaborative investment models.

1.4.3. Final Reflections

The project demonstrated that NoSQL databases provide an adaptable framework for renewable energy data management. Key benefits included:

- **Enhanced Query Efficiency:** Complex analytical queries performed efficiently without requiring rigid schema modifications.
- **Improved Data Structuring:** The use of embedded subdocuments streamlined the representation of financial, environmental, and operational metrics.
- **Scalability for Future Growth:** The flexible schema allows for easy integration of new projects and data sources, supporting long-term sustainability goals.

Moving forward, further enhancements can focus on **machine learning integration** for predictive energy modeling and **real-time data processing** to improve monitoring and decision-making in renewable energy investments.