Assessing the Sustainability of Nuclear Energy: Efficiency, Safety, and Resource Perspectives through NoSQL Analysis

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November 2025

Abstract

This study investigates the sustainability of nuclear energy compared to other electricity sources, focusing on three main dimensions: efficiency, safety, and resource availability. Using a curated collection of datasets imported into a MongoDB database, we analyze global and U.S.-specific nuclear power plant data, uranium production and prices, and safety metrics measured in deaths per terawatt-hour. The findings provide a data-driven overview of nuclear energy's performance, highlighting trends in capacity, generation, and safety, as well as the availability of uranium resources to support continued nuclear production. The study aims to offer an objective and balanced assessment of nuclear energy within the broader electricity generation landscape.

1 Introduction

Nuclear energy plays a critical role in the global effort to decarbonize electricity production and mitigate climate change. Despite its low greenhouse gas emissions and high energy density, nuclear power remains a subject of debate due to concerns over safety, waste management, and the long-term availability of uranium resources. Understanding the efficiency, safety, and resource dynamics of nuclear energy is essential for policymakers, energy planners, and researchers seeking to design sustainable energy systems.
This report addresses the following research question:

How sustainable is nuclear energy compared to other electricity sources, in terms of efficiency, safety, and resource availability?

To answer this question, we employ a data-driven approach using multiple datasets that capture nuclear power plant characteristics, electricity generation, uranium production, and mortality rates associated with different energy sources. The analysis is conducted using MongoDB, allowing for flexible data storage, aggregation, and querying. The results provide insights into global and national trends, the comparative safety of nuclear power, and the availability of uranium resources necessary to support nuclear electricity production.

2 Datasets and Collections

The analysis in this report is based on several CSV files imported into a MongoDB database, all related to nuclear energy. The data used in this study were obtained from a publicly available dataset on Nuclear Energy Datasets by Alistair King on Kaggle. Additional data sources and references will be listed in the References section at the end of this report.

2.1 Collections Imported into MongoDB

Each CSV file was imported into a dedicated MongoDB collection within a database named `energia`. The main collections and their contents are described below:

- **power_plant_database_global**
  Source: Kaggle / Global Power Plant Database
  Description: Contains global power plant information, including location, capacity (MW), primary fuel type, estimated generation, and ownership. Used to analyze nuclear plant distribution, capacity, and comparative performance with other energy sources.

- **number_of_plants_producing_uranium_in_us**
  Source: U.S. Energy Information Administration (EIA)
  Description: Yearly data on uranium production facilities in the U.S., including conventional and non-conventional mills, in-situ recovery plants, and byproduct recovery operations. Used to assess U.S. uranium production trends and resource availability.

- **rates_death_from_energy_production_per_twh**
  Source: Scientific literature compiled within the dataset
  Description: Provides mortality rates associated with electricity generation from various energy sources (deaths per TWh). Used to compare the relative safety of nuclear energy with other sources.

- **uranium_production_summary_us**
  Source: U.S. Energy Information Administration (EIA)
  Description: Annual statistics on U.S. uranium mining and production, including mine output, concentrate production, shipments, employment, and exploration expenditures. Used to evaluate domestic uranium supply trends.

- **uranium_purchase_price_us**
  Source: U.S. Energy Information Administration (EIA)
  Description: Weighted-average uranium purchase prices for U.S. nuclear reactors, categorized by source and contract type. Used to analyze uranium procurement costs over time.

- **us_nuclear_generating_statistics_1971_2021**
  Source: U.S. Nuclear Regulatory Commission (NRC)
  Description: Annual data on nuclear electricity generation, installed capacity, and capacity factors in the United States. Used to examine long-term generation trends and correlate them with uranium supply.

- **world_electricity_generation**
  Source: Our World in Data
  Description: Global nuclear electricity generation over multiple years, with monthly granularity and share of total electricity. Used to analyze temporal trends in nuclear power production.

- **world_nuclear_energy_generation**
  Source: Our World in Data
  Description: Annual data on nuclear electricity generation and percentage share for individual countries, regions, and aggregated entities. Used to compare nuclear contributions across different geographic areas.

3 Methodology

The methodology adopted in this study focuses on the preparation, organization, and analysis of nuclear energy data using a NoSQL database approach. All datasets were processed and analyzed within a MongoDB environment, chosen for its flexibility in handling large, heterogeneous datasets and for its ability to support complex analytical operations through aggregation pipelines.

3.1 Data Import and Preparation

To perform the analyses in MongoDB, all the selected datasets were first imported into the database environment. The original data were provided as CSV files, each representing a specific aspect of nuclear and renewable energy production.
In the first step, all CSV files were imported into a database named `nuclear_energy`, with each file loaded as a separate collection. The data were then converted into JSON format to enable more advanced analyses using MongoDB's aggregation framework and imported into a new database named `energia`.
After this process, both databases contained structured, queryable data collections corresponding to the original datasets. The `energia` database, in particular, was used for the analyses presented in this study, allowing for flexible and efficient querying through MongoDB's aggregation pipelines.
All the scripts and commands used for importing and preprocessing the data are provided separately in the file `code.txt`.

3.2 Tools and Analytical Approach

The primary tools and technologies used in this analysis include:

- **MongoDB**: a document-oriented NoSQL database used for storing and querying large and complex datasets efficiently.
- **MongoDB Command-Line Tools**: in particular, `mongoimport` was used to import both CSV and JSON datasets directly into the database.
- **MongoDB Aggregation Framework**: used to perform in-database analytics such as filtering, grouping, sorting, and calculating statistical

measures. This enabled analyses including total generation capacity by energy type, temporal evolution of nuclear output, spatial aggregation by geographic bands, and comparisons between nuclear and other energy sources.

This approach allowed for a scalable and flexible analysis framework that integrates multiple datasets, supporting spatial, temporal, and comparative perspectives to investigate the global role and efficiency of nuclear energy.

4 Overview of Queries

To explore the sustainability of nuclear energy, a series of ten MongoDB queries were executed on the imported datasets. The queries can be broadly grouped into four thematic areas:

1. **Efficiency and Capacity:** Queries 1 and 2 focus on the total capacity of nuclear plants globally and by country, allowing comparison with other energy sources and identification of leading nuclear producers.

2. **Share of Electricity and Growth Trends:** Queries 3 and 4 examine the contribution of nuclear energy to national electricity mixes and identify countries with the largest recent increases in nuclear generation.

3. **Spatial Distribution:** Query 5 evaluates the geographic concentration of nuclear power plants by latitude and longitude bands, revealing patterns of capacity density across regions.

4. **Safety and Resource Analysis:** Queries 6 through 10 investigate nuclear safety relative to other energy sources, compare nuclear and solar energy production, assess estimation errors, and analyze the relationship between U.S. uranium production, nuclear generation, and uranium costs over time.

Each query is accompanied by commentary on its objective, the main results, and the interpretation of findings. For readers primarily interested in the overall insights rather than the technical implementation, the key observations and conclusions are summarized in the subsequent section. The detailed queries are provided for completeness and reproducibility.

4.1 Query 1: Global Power Generation Capacity by Primary Fuel Type

Objective:
To compare the number of power plants and the total installed generation capacity across different primary fuel types, highlighting the relative efficiency of nuclear energy in terms of capacity per plant.
MongoDB Operation:
The query was executed on the `power_plant_database_global` collection. The aggregation pipeline:

- groups all records by `primary_fuel`,
- counts the total number of plants and sums their installed capacity (in megawatts),
- sorts results in descending order of total capacity.

Result: The aggregation produced the following key figures:

Energy Source	Number of Plants	Total Capacity (MW)
Coal	2,330	1,965,541.0
Gas	3,998	1,493,050.6
Hydro	7,156	1,053,159.6
Nuclear	**195**	**407,911.8**
Wind	5,344	263,053.7
Oil	2,320	261,878.7
Solar	10,665	188,312.3
Biomass	1,430	34,281.3
Waste	1,068	14,748.7
Geothermal	189	12,687.8

Despite having only **195 nuclear power plants worldwide**, the total installed nuclear capacity reaches approximately **407 GW**, making it the **fourth-largest contributor** to global electricity capacity. In contrast, fossil fuel sources such as coal and gas require thousands of facilities to reach comparable capacity levels, implying a far lower average generation capacity per plant.
Comment / Interpretation:
These results demonstrate the intrinsic efficiency of nuclear power generation. Each nuclear facility provides an average capacity of over **2,000 MW**

per plant, whereas coal and gas facilities typically produce below 500 MW on average. This suggests that nuclear energy achieves high output with a smaller physical and environmental footprint, supporting its classification as an efficient and scalable low-carbon energy source. However, the concentration of capacity in a small number of plants also implies higher systemic risk in case of outages or shutdowns, which remains a relevant consideration for energy planners.

4.2 Query 2: Global Distribution of Nuclear Power Capacity

Objective:
To determine which countries possess the largest installed nuclear capacity and assess the global distribution of nuclear energy production. This analysis provides insight into where nuclear power plays the most significant role in national energy systems and helps identify regions of strategic importance for further investigation.
MongoDB Operation:
The query was executed on the `power_plant_database_global` collection. The aggregation pipeline:

- filters records with `primary_fuel = "Nuclear"`,
- groups results by country and sums total capacity (MW),
- sorts in descending order to identify top nuclear-producing nations.

Result: The following table summarizes the ten countries with the highest total nuclear generation capacity:

Country	Total Nuclear Capacity (MW)
United States of America	104,233.1
France	63,130.0
Japan	42,537.0
China	33,402.0
Russia	28,168.0
South Korea	23,076.0
Canada	14,254.0
Ukraine	13,835.0
Germany	11,171.0
Sweden	9,762.0

The results indicate that the **United States** leads with over **104 GW** of installed nuclear capacity, followed by **France** with approximately **63 GW**. Together, these two countries account for nearly half of the total global nuclear capacity. Asian nations such as **Japan**, **China**, and **South Korea** also rank among the top producers, reflecting the significant regional investments in nuclear technology.

Comment / Interpretation:

The dominance of the United States and France illustrates how nuclear energy remains central to their national energy strategies. The United States combines a large number of older reactors with high operational reliability, while France relies heavily on nuclear power to meet domestic electricity demand, generating more than 70% of its electricity from this source. These findings also point to strategic areas for further analysis — particularly the United States — where the relationship between uranium resource availability and nuclear output will be examined in subsequent queries.

4.3 Query 3: Share of Electricity from Nuclear Energy (2023)

Objective:

To evaluate the contribution of nuclear energy to total electricity generation across countries in 2023, identifying those where nuclear plays a particularly significant role. The analysis considers only countries whose nuclear share exceeds the global average, highlighting regions with a strong reliance on nuclear power.

MongoDB Operation:
The query was executed on the `world_nuclear_energy_generation` collection. The aggregation pipeline:

- computes the global average share of electricity from nuclear power in 2023,
- filters countries with a share above that average,
- sorts in descending order and rounds results to two decimals.

Result: The global average share of electricity generated from nuclear power in 2023 was approximately **16.8%**. Only a limited number of countries exceeded this threshold, with the top values summarized below:

Country	Nuclear Share of Electricity (%)
France	65.29
Slovakia	61.90
Hungary	44.47
Finland	42.48
Belgium	40.56
Bulgaria	40.41

Comment / Interpretation:
The results show that **France** remains the most nuclear-dependent nation globally, with nearly two-thirds of its electricity generated from nuclear energy. Central and Eastern European countries—**Slovakia**, **Hungary**, and **Bulgaria**—also display strong reliance on nuclear power, often due to inherited Soviet-era infrastructure and limited fossil fuel alternatives. In contrast, major producers such as the **United States** and **Russia** fall below the global average, reflecting more diversified energy mixes. Overall, nuclear energy's contribution to national grids is highly uneven, being dominant in a few European countries but secondary elsewhere.

4.4 Query 4: Countries with the Largest Increase in Nuclear Electricity Generation (2015–2023)

Objective:
To identify which countries have experienced the largest recent increases in

nuclear electricity generation, indicating active nuclear expansion or recovery after previous shutdowns. The focus is on annual generation changes after 2015, to capture contemporary trends in nuclear development.

MongoDB Operation:

The query was executed on the `world_nuclear_energy_generation` collection. The aggregation pipeline:

- filters data for years after 2015,
- uses `$setWindowFields` to compute year-to-year generation changes,
- extracts maximum positive annual increase for each country,
- sorts results in descending order of generation growth.

Result: The analysis revealed the following countries with the most significant recent annual increases in nuclear generation:

Country	**Year**	**Increase (TWh)**
China	2019	53.7
France	2023	40.92
Japan	2023	25.67

Comment / Interpretation:

China demonstrates the largest single-year increase, reflecting its aggressive nuclear expansion policy and consistent addition of new reactors since 2010. France shows a substantial rebound in 2023, suggesting recovery after several years of maintenance-related production drops. Japan's positive change in 2023 aligns with the gradual reactivation of reactors that were shut down following the Fukushima accident in 2011. Overall, these results highlight how Asian and European nations remain key drivers in maintaining and expanding global nuclear electricity generation capacity.

4.5 Query 5: Geospatial Distribution of Nuclear Power Capacity (5°×5° Latitude–Longitude Bands)

Objective:

To analyze the geographical distribution of global nuclear power plants by aggregating total capacity within 5°×5° latitude–longitude bands. This approach provides a spatial perspective on where nuclear capacity is concentrated, distinguishing between regions with high *density* (many plants or large capacity in a small area) and regions with high *dispersion* (plants spread across vast territories).

MongoDB Operation:

The analysis was performed on the `power_plant_database_global` collection. The query filters only nuclear facilities with valid coordinates and divides the Earth's surface into 5-degree bands of latitude and longitude. For each geographical band, the aggregation computes:

- the total number of nuclear plants (`plant_count`),
- the total installed capacity (`total_capacity_mw`),
- the list of countries contributing to that band.

The output is sorted by total capacity, highlighting the most nuclear-dense regions.

Result: The top latitude–longitude bands with the highest nuclear generation capacity are as follows:

Latitude Band	Longitude Band	Country	Total Capacity (MW)
45°–50°	0°–5°	France	27,890
35°–40°	125°–130°	South Korea	23,076
35°–40°	135°–140°	Japan	20,046

Comment / Interpretation:

The results reveal that France exhibits the highest concentration of nuclear capacity within a small geographic area, reflecting its national dependence on nuclear power for electricity generation. South Korea and Japan also demonstrate strong regional concentrations, showing how smaller, densely populated nations tend to cluster their nuclear infrastructure. Conversely, large countries such as the United States appear across multiple geographic bands, distributing their nuclear generation over a broader territory. This spatial analysis highlights the difference between high *capacity density* (intensive generation in small regions) and high *capacity distribution* (generation spread across large nations).

4.6 Query 6: Comparative Safety of Energy Sources (Deaths per TWh)

Objective:
To compare the safety of different electricity generation sources by calculating deaths per TWh. Each alternative energy source is measured against nuclear energy to determine how many times more dangerous it is per unit of electricity produced.

MongoDB Operation:
The analysis uses the `rates_death_from_energy_production_per_twh` collection. The aggregation pipeline:

- separates nuclear from other sources,
- calculates the ratio of deaths per TWh for each alternative relative to nuclear,
- sorts results in descending order of relative danger.

Result: The following table shows the number of deaths per TWh for each source and how many times more dangerous it is compared to nuclear:

Energy Source	Deaths per TWh	Times More Dangerous than Nuclear
Brown coal	32.72	1,090.67
Coal	24.62	820.67
Oil	18.43	614.33
Biomass	4.63	154.33
Gas	2.82	94.03
Hydropower	1.30	43.33
Wind	0.035	1.17
Solar	0.019	0.63

Comment / Interpretation:
The results highlight that fossil fuels, particularly Brown coal and Coal, are several hundred times more dangerous than nuclear per unit of electricity produced. Renewables such as wind and solar have very low death rates, comparable to or even below nuclear in this dataset. This analysis demonstrates nuclear energy's safety advantage over traditional fossil fuels while providing context relative to renewable sources.

4.7 Query 7: Comparison of Nuclear and Solar Energy by Country

Objective:
To compare nuclear and solar electricity generation by country, including estimated deaths per TWh. This analysis highlights the differences in energy output and relative safety between nuclear and solar energy.
MongoDB Operation:
The analysis was conducted on the `power_plant_database_global` collection. The aggregation pipeline:

- separates nuclear and solar power plants using the `$facet` operator,
- computes total electricity generation (GWh) for each country and estimates deaths using the per-TWh mortality rate,
- merges nuclear and solar results for each country,
- sorts countries by nuclear generation in descending order.

Result: The top countries for nuclear generation in 2017 and their corresponding solar generation and estimated deaths are:

Country	**Nuclear GWh**	**Nuclear Deaths**	**Solar GWh**	**Solar Deaths**
United States	826,911	57.88	73,706	1.47
France	381,719	26.72	8,348	0.17
Japan	339,800	23.79	9,189	0.18

Comment / Interpretation:
While nuclear energy produces significantly more electricity than solar in these countries (e.g., the U.S. produces ∼11 times more nuclear GWh than solar), the associated deaths per unit of energy are very low. The higher absolute number of nuclear deaths reflects its large-scale production rather than higher risk per TWh. This illustrates that nuclear power can generate massive amounts of electricity with comparatively low mortality risk per unit of energy, highlighting its high energy density relative to solar.

4.8 Query 8: Comparison of Actual vs. Estimated Nuclear Generation (2017)

Objective:
To assess the accuracy of estimated nuclear generation for 2017 by comparing

the real output of each plant with its estimated value. Absolute and percent errors are calculated to highlight plants with the largest discrepancies.

MongoDB Operation:

The analysis was performed on the `power_plant_database_global` collection. The query filters only nuclear plants with both real and estimated generation data. For each plant, it computes:

- `absolute_error` = |Real Generation - Estimated Generation| (GWh)
- `percent_error` = 100 × `absolute_error` / Real Generation

The results are sorted by `percent_error` in descending order.

Result (Top Plants by Percent Error):

Country	Pla.Nam	(GWh)	Estimated (GWh)	Abs. Err.(GWh)	Per Error(%)
BEL	TIHANGE 1N	1,775.31	6,679.11	4,903.80	276.22
FRA	FESSENHEIM	5,709.95	10,641.93	4,931.98	86.38
DEU	BROKDORF	5,480.32	9,946.24	4,465.92	81.49
IND	KUNDANKULAM	7,894.40	13,384.29	5,489.89	69.54
SWE	OSKARSHAMN	11,073.70	18,517.23	7,443.53	67.22
USA	GRAND GULF	7,364.65	11,423.93	4,059.28	55.12

Comment / Interpretation:

The results reveal that estimates can significantly deviate from actual generation. The TIHANGE 1N plant in Belgium shows the largest discrepancy, with estimated generation almost 3 times the actual value. Other plants, such as Fessenheim (France) and Brokdorf (Germany), also exhibit substantial overestimation. This highlights potential issues in predictive models or data sources used for generation estimates and emphasizes the need for careful validation when planning or analyzing nuclear output.

4.9 Query 9: U.S. Uranium Production and Nuclear Generation Over Time

Objective:

To examine the relationship between U.S. uranium mining activity (production and employment) and total nuclear electricity generation over time. The goal is to determine whether domestic uranium production trends align with the stability of U.S. nuclear generation output.

MongoDB Operation:
The analysis was performed on the `uranium_production_summary_us` collection, joined with `us_nuclear_generating_statistics_1971_2021` using a `$lookup` on the year field. The aggregation:

- merges uranium mining data with nuclear generation statistics,
- extracts numeric values for mine production (million lbs) and employment,
- projects comparable yearly indicators for uranium output, workforce, and total nuclear generation (MWh),
- sorts the results in descending order by year.

Result: A subset of results from 2021 to 2012 is presented below.

Year	Uran. Prod. (mln lbs)	Employees	Nucl. Gen. (MWh)
2021	0.02	207	778,151,500
2020	–	225	789,878,863
2019	0.20	265	809,409,262
2018	0.70	372	807,084,477
2017	1.20	424	804,949,635
2016	2.50	560	805,693,948
2015	3.70	625	797,177,877
2014	4.90	787	797,165,982
2013	4.60	–	789,016,473
2012	4.30	–	769,331,249

Comment / Interpretation:
The results reveal a pronounced decline in domestic uranium production and mining employment over the past decade, falling from around 4–5 million pounds in 2012–2014 to nearly zero in 2021. Despite this collapse in local uranium output, nuclear electricity generation has remained remarkably stable, consistently around 780–810 million MWh per year.
This divergence strongly indicates a growing reliance on imported uranium to sustain reactor operations. In other words, while U.S. nuclear energy output shows operational consistency, the supply chain has become increasingly dependent on foreign uranium sources rather than domestic mining. The data underscores a strategic vulnerability: stable nuclear generation is being maintained not by internal production, but by global uranium trade.

4.10 Query 10: U.S. Nuclear Generation and Uranium Costs Over Time

Objective:
To analyze the relationship between U.S. nuclear electricity generation and uranium costs over time. This analysis estimates the total uranium required each year (0.007 lbs per MWh) and multiplies it by the annual uranium price to calculate the total uranium cost.

MongoDB Operation:
The query was performed on `us_nuclear_generating_statistics_1971_2021` joined with `uranium_purchase_price_us` using a `$lookup` on the year. For each year, the aggregation computes:

- `nuclear_generation` — total nuclear electricity generation (MWh)
- `uranium_needed_pounds` — estimated uranium required in lbs
- `uranium_price_usd_per_lb` — uranium purchase price in USD per pound
- `total_uranium_cost_usd` — total estimated uranium cost in USD

The results are sorted by year in descending order.
Result: A subset of the results from 2021 to 2012 is presented below:

Year	Nucl. Gen. (MWh)	Uran. Need (lbs)	Uran. Pr. (USD/lb)	Tot. Uran. Cost (USD)
2021	778,151,500	5,447,060	33.91	184,709,822
2020	789,878,863	5,529,152	33.27	183,954,888
2019	809,409,262	5,665,865	35.59	201,648,129
2018	807,084,477	5,649,591	38.81	219,260,640
2017	804,949,635	5,634,647	38.80	218,624,321
2016	805,693,948	5,639,858	42.43	239,299,160
2015	797,177,877	5,580,245	44.13	246,256,218
2014	797,165,982	5,580,162	46.16	257,580,272
2013	789,016,473	5,523,115	51.99	287,146,765
2012	769,331,249	5,385,319	54.99	296,138,678

Comment / Interpretation:
Between 2012 and 2021, U.S. nuclear generation remained largely stable, while uranium prices and total uranium costs declined. Despite steady electricity output, total uranium expenditure fell by over a third, driven mainly by lower uranium market prices rather than changes in production efficiency. This highlights how raw material costs can significantly affect the economics of nuclear energy even when operational performance is unchanged.

5 Conclusions

This study evaluated the sustainability of nuclear energy compared to other electricity sources, focusing on three key dimensions: **efficiency**, **safety**, and **resource availability**. The analysis integrated global datasets on power plants, nuclear generation, and mortality rates to provide a data-driven assessment.

5.1 Efficiency and Capacity

The global installed capacity by energy source (Figure 1) demonstrates that nuclear power is highly efficient. Despite having only 195 plants worldwide, nuclear energy contributes approximately 407 GW of installed capacity, making it the fourth-largest source globally. In contrast, fossil fuels like coal and gas require thousands of facilities to reach similar capacity levels, highlighting nuclear's high energy output per facility.

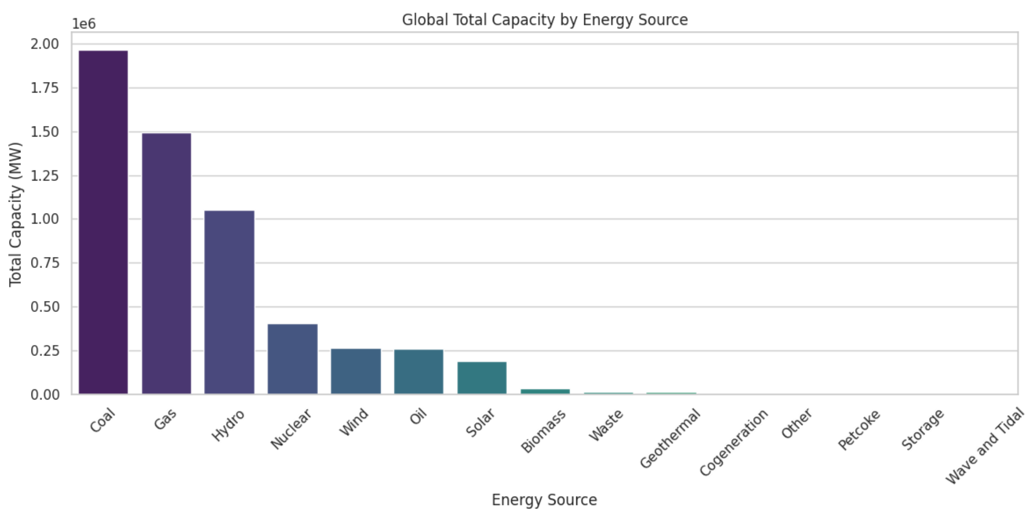

Figure 1: Global Installed Capacity per Energy Source.

Nuclear plants provide high energy density, achieving large-scale electricity generation with a smaller environmental footprint per unit of energy produced. This supports the classification of nuclear power as an efficient and scalable low-carbon energy source.

5.2 Contribution to the National Electricity Mix

The share of electricity produced from nuclear energy by country (Figure 2) shows that certain nations, such as France and Slovakia, rely heavily on nuclear power, with nuclear contributions exceeding 60% of total electricity. Other major producers like the United States and Russia exhibit a more diversified mix, with nuclear forming a smaller fraction of total generation.

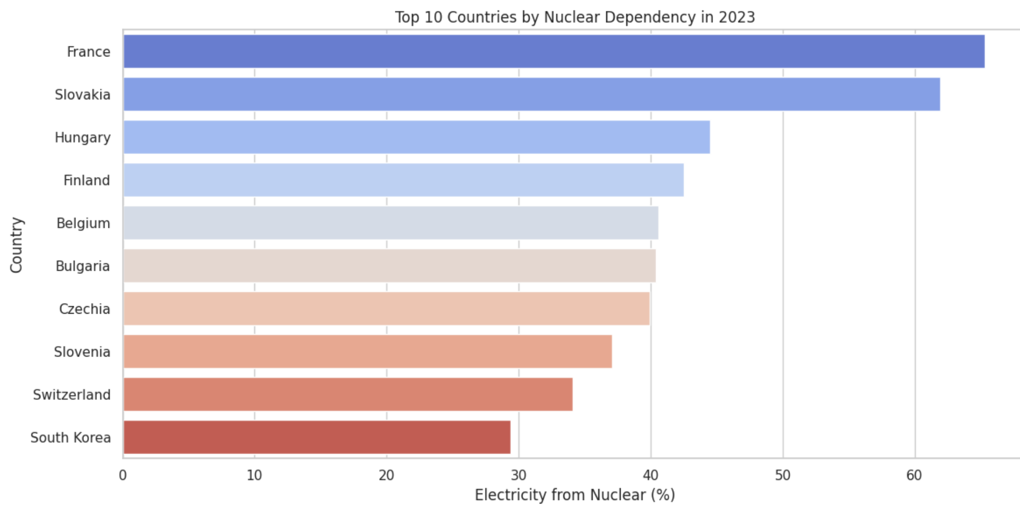

Figure 2: Top 10 countries by share of electricity from nuclear power.

Nuclear energy plays a crucial role in stabilizing electricity supply in countries that heavily rely on it, contributing significantly to low-carbon baseload electricity. Its uneven geographic distribution indicates strategic areas where nuclear sustainability is most impactful.

5.3 Safety Comparison

The comparative mortality rates per TWh of electricity produced (Figure 3) reveal that nuclear power is one of the safest sources, with deaths per TWh far lower than coal, oil, or biomass. Renewable sources such as wind and solar also demonstrate low mortality rates, but nuclear achieves high output with minimal deaths relative to fossil fuels.

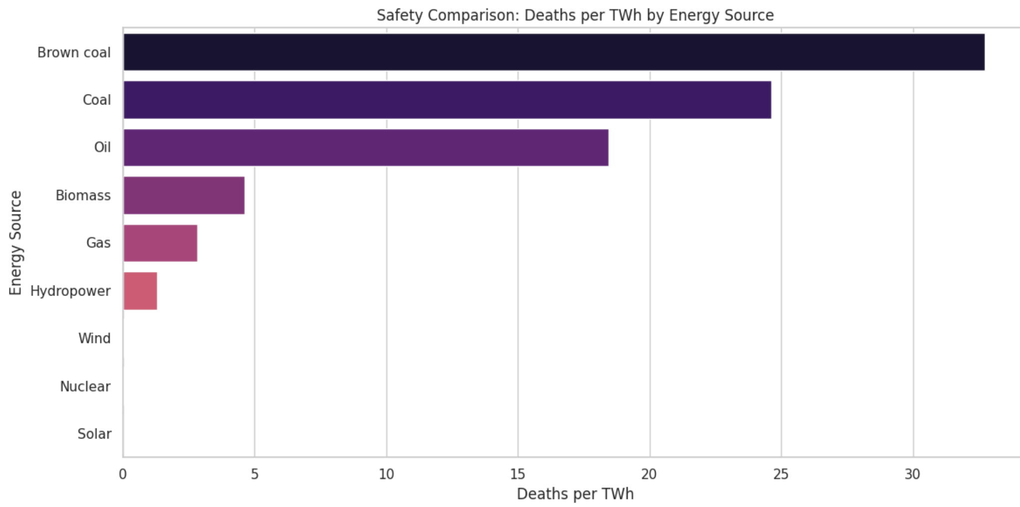

Figure 3: Deaths per TWh by energy source.

The safety profile of nuclear energy, combined with its high efficiency and contribution to national electricity supply, underscores its sustainability advantages. Low mortality risk per unit of electricity positions nuclear power as a safe option for large-scale, low-carbon energy production.

5.4 Overall Assessment

Integrating efficiency, contribution to the electricity mix, and safety, nuclear energy proves to be a sustainable electricity source in countries where it is deployed extensively.
Beyond these three key aspects, the datasets also reveal additional insights. Historical trends in U.S. nuclear generation demonstrate remarkable stability in output over decades, highlighting reliability and resilience in energy supply. Data on uranium production and procurement show that, while nuclear relies on finite resources, supply chains are diverse and manageable, and improvements in fuel efficiency further enhance sustainability.
Taken together, these analyses indicate that nuclear energy balances high efficiency, substantial low-carbon electricity contribution, and strong safety performance. Although challenges such as waste management and regulatory oversight remain, evidence from multiple datasets supports the conclusion that nuclear power is a sustainable and viable component of modern electricity systems.

References

The data used in this analysis comes from the following sources:

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