Global Energy Production & Consumption-Analysis

ABSTRACT

This study examines trends in primary energy production and consumption from 1973 to 2022, focusing on the dominance of fossil fuels, the growth of renewable energy, and the role of nuclear power. Findings reveal significant shifts in energy dynamics, including a marked increase in renewable energy since 2005 and a period of energy surplus after 2019. The study identifies key challenges, such as reducing dependence on fossil fuels, improving energy efficiency, and addressing vulnerabilities related to energy imports. Based on these findings, recommendations are made for the continued transition to renewable energy, the enhancement of energy efficiency, and the exploration of energy exports to secure a more sustainable and independent energy future.

INTRODUCTION

The global energy landscape has changed significantly over the past five decades, driven by technological advancements and shifts in production and consumption patterns. Fossil fuels have historically dominated global energy production, but growing concerns about climate change, environmental degradation, and energy security have led to a push for cleaner, more sustainable energy sources. In particular, renewable energy and nuclear power have seen notable increases in their contributions to the global energy mix.

This study focuses on analyzing the patterns of primary energy production and consumption from 1973 to 2022, with an emphasis on identifying trends and shifts in energy sources. By examining data on fossil fuels, renewable energy, and nuclear electric power, the study aims to provide insights into the current state of energy production, highlight the key challenges facing energy security, and offer recommendations for moving toward a more sustainable and efficient energy future.

PROBLEM STATEMENT

The primary challenge in the global energy sector is the unsustainable reliance on fossil fuels, which has led to concerns about long-term energy security, environmental sustainability, and economic stability. Despite growing investments in renewable energy and nuclear power, fossil fuels remain the most produced and consumed energy source worldwide. This creates significant vulnerabilities, particularly in times of energy crises or geopolitical instability.

Furthermore, energy consumption patterns have shown periods of imbalance, with some years seeing consumption outstripping production, while others indicate the potential for export or storage due to surplus energy production. These fluctuations underscore the need for better

energy management, improved efficiency, and diversification of energy sources to reduce dependence on fossil fuels and mitigate the risks of energy shortages or crises.

PROJECT OBJECTIVES

1. **Analyze Energy Production and Consumption Trends**: Examine the historical trends in primary energy production and consumption from 1973 to 2022, identifying key shifts and patterns in fossil fuels, renewable energy, and nuclear power.
2. **Evaluate the Ratio of Energy Production to Consumption**: Assess the ratio of energy production to consumption over the years, with a focus on the period since 2019, when production exceeded consumption, to understand the implications for energy security and potential for export or storage.
3. **Identify Challenges and Risks**: Highlight the challenges associated with energy dependence, the historical risk of energy crises, and the vulnerability to fossil fuel shortages or import reliance.
4. **Provide Recommendations for Energy Transition**: Offer recommendations for reducing reliance on fossil fuels through the promotion of renewable energy, enhancing energy efficiency, supporting nuclear power development, and improving energy security through diversification and better demand-side management.
5. **Examine Opportunities for Energy Exports**: Explore the potential for energy exports, particularly in the context of a production-to-consumption ratio above 1 since 2019, suggesting opportunities for energy surplus and export to neighbouring regions or international markets.

METHODOLOGY

For this project, I used **SQL** for data cleaning and analysis and **Microsoft Power BI** to create interactive dashboards and visualizations to explore energy production, consumption trends and the shift toward renewable and nuclear energy.

DATA DESCRIPTION

The datasets for this project were sourced from GitHub and Our World in Data. You can access them directly from the provided links.

DATA DICTIONARY

The project utilizes the following datasets:

1. **Consumption**: Data on total fossil fuel consumption, nuclear electric power consumption, total renewable energy consumption, primary energy net exports, and total primary energy consumption.

2. **Production**: Data on total fossil fuel production, nuclear electric power production, total renewable energy production, primary energy imports, and total primary energy production.
3. **Primary Energy Consumption**: Total primary energy consumption in TWh.
4. **Change in Energy Consumption**: Annual percentage change in primary energy consumption.
5. **World Energy Overview**: A general overview of global energy production and cconsumption.

DATA IMPORT AND DATABASE SETUP

I imported the data into MySQL Workbench using the Import Table Wizard for cleaning and analysis.

DATA CLEANING AND TRANSFOMATION

The following steps were taken to clean, transform, and standardize the dataset in MySQL;

```sql
-- DATA CLEANING & STANDARDIZATION
-- Convert data type to date for columns DATE
UPDATE consumption
SET Date = STR_TO_DATE(Date,"%d-%m-%Y");

ALTER TABLE consumption
Modify Date DATE;

UPDATE production
SET Date = STR_TO_DATE(Date,"%d-%m-%Y");

ALTER TABLE production
Modify Date DATE;

UPDATE world_energy_overview
SET Date = STR_TO_DATE(Date,"%d-%m-%Y");

ALTER TABLE world_energy_overview
Modify Date DATE;

```

DATA ANALYSIS AND QUERYING

I used SQL to conduct the following Analysis of the data:

1. **How many entities are there?**

```
22      -- How many entities are there
23 •    SELECT COUNT(DISTINCT Entity) as Total_Entities
24      FROM primary_energy_consumption;
25
26 •    SELECT DISTINCT Entity
27      FROM primary_energy_consumption;
```

Result Grid | Filter Rows: | Export: | Wrap Cell Content:

Total_Entities
265

There is a total of 265 entities which some are shown below:

```
26 •    SELECT DISTINCT Entity
27      FROM primary_energy_consumption;
28
```

Result Grid | Filter Rows: | Export: | Wrap Cell Conte

Entity
Afghanistan
Africa
Africa (EI)
Africa (EIA)
Albania
Algeria
American Samoa
Angola
Antarctica
Antigua and Barbuda
Argentina
Armenia
Aruba
Asia
Asia & Oceania (EIA)

2.What are the Monthly Trends in Consumption and Production and Balance?

```sql
-- Monthly Trends in Consumption and Production and Balance
SELECT
    YEAR(Date) AS Year,
    MONTH(Date) AS Month,
    Total_Primary_Energy_Production AS Monthly_production,
    Total_Primary_Energy_Consumption AS Monthly_consumption,
    (SUM(Total_Primary_Energy_Production) - SUM(Total_Primary_Energy_Consumption)) AS Balance
FROM world_energy_overview
GROUP BY YEAR(Date), MONTH(Date),Monthly_production,Monthly_consumption
ORDER BY Year, Month;
```

Result Grid | Filter Rows: | Export: | Wrap Cell Content:

Year	Month	Monthly_production	Monthly_consumption	Balance
1973	1	5.404715	7.223873	-1.8191579999999998
1973	2	5.155115	6.592366	-1.4372509999999998
1973	3	5.419556	6.521439	-1.101883
1973	4	5.160812	5.941729	-0.7809169999999996
1973	5	5.411246	6.07194	-0.6606939999999994
1973	6	5.167296	5.802683	-0.6353869999999997
1973	7	5.191492	5.951909	-0.7604169999999995
1973	8	5.480638	6.191657	-0.7110190000000003

3. What are the Years and months sorted by production, from highest to lowest?

Don't Limit

```sql
-- Years and months sorted by production, from highest to lowest
SELECT
    Year(Date) as Year,
    Month(Date) as Month,
    ROUND(SUM(Total_Primary_Energy_Production),2) AS Total_production,
    ROUND(SUM(Total_Primary_Energy_Consumption),2) AS Total_consumption
FROM world_energy_overview
GROUP BY YEAR(Date), MONTH(Date)
ORDER BY Total_production DESC;
```

Result Grid | Filter Rows: | Export: | Wrap Cell Content:

Year	Month	Total_production	Total_consumption
2022	8	8.81	8.53
2020	1	8.78	8.97
2019	8	8.77	8.57
2022	7	8.77	8.58
2019	12	8.76	8.95
2022	10	8.76	7.81
2022	5	8.73	7.94
2022	3	8.68	8.54
2021	12	8.67	8.75
2019	5	8.65	7.95

Result 60

From the results above, **August 2022** had the **highest** Total Primary Energy Production of **8.81 TWh** while **February 1978** had the **lowest** Total Primary Energy Production of **4.31 TWh**.

4. What are the Years and months sorted by consumption, from highest to lowest?

```
40      -- Years and months sorted by consumption, from highest to lowest
41  •   SELECT
42          Year(Date) as Year,
43          Month(Date) as Month,
44          ROUND(SUM(Total_Primary_Energy_Consumption),2) AS Total_consumption,
45          ROUND(SUM(Total_Primary_Energy_Production),2) AS Total_production
46      FROM world_energy_overview
47      GROUP BY YEAR(Date), MONTH(Date)
48      ORDER BY Total_consumption DESC;
```

Result Grid | Filter Rows: | Export: | Wrap Cell Content:

Year	Month	Total_consumption	Total_production
2018	1	9.66	7.75
2014	1	9.59	7.18
2019	1	9.55	8.53
2022	1	9.51	8.53
2008	1	9.41	6.2
2004	1	9.35	6.02
2005	1	9.29	5.97
2011	1	9.29	6.49
2015	1	9.29	7.71
2001	1	9.23	6.11

From the results above, **January 2018** had the **highest** Total Primary Energy Consumption of **9.66 TWh** while June 1975 had the **lowest** Total Primary Energy Consumption of **5.44 TWh.**

5.Primary energy consumption by Entity

```sql
-- Consumption by Entity
SELECT Entity, Year, Primary_energy_consumption_TWh
FROM primary_energy_consumption
GROUP BY Entity, Year, Primary_energy_consumption_TWh
ORDER BY Primary_energy_consumption_TWh DESC;
```

Result Grid | Filter Rows: | Export: | Wrap Cell Content: | Fetch rows:

Entity	Year	Primary_energy_consumption_TWh
World	2023	172119.06
World	2022	168708.2
Non-OPEC (EIA)	2021	165975.98
World	2021	165729.03
Non-OPEC (EIA)	2019	164428.64
Non-OPEC (EIA)	2018	163605.27
World	2019	163346.6
World	2018	161518.44
Non-OPEC (EIA)	2017	159625.83
Non-OPEC (EIA)	2020	158359.45
World	2020	157667.72
World	2017	157252.06
Non-OPEC (EIA)	2016	156564.4
Non-OPEC (EIA)	2015	155208.78
Non-OPEC (EIA)	2014	155088.5

6. What is the consumption like by energy type and year?

```sql
-- Consumption by Energy Type and Year
SELECT YEAR(Date) AS Year,
       ROUND(SUM(Total_Fossil_Fuels_Consumption),2) AS Fossil_Fuels,
       ROUND(SUM(Nuclear_Electric_Power_Consumption),2) AS Nuclear_Power,
       ROUND(SUM(Total_Renewable_Energy_Consumption),2) AS Renewable_Energy
FROM consumption
GROUP BY YEAR(Date);
```

Result Grid | Filter Rows: | Export: | Wrap Cell Content:

Year	Fossil_Fuels	Nuclear_Power	Renewable_Energy
1973	70.28	0.91	4.41
1974	67.87	1.27	4.74
1975	65.32	1.9	4.69
1976	69.07	2.11	4.73
1977	70.95	2.7	4.21
1978	71.81	3.02	5.01
1979	72.84	2.78	5.12
1980	69.78	2.74	5.43

Result 11

7. What is the production like by energy type and year?

```
89      -- Production by Energy Type and Year
90  •   SELECT YEAR(Date) AS Year,
91             ROUND(SUM(Total_Fossil_Fuels_Production),2) AS Fossil_Fuels,
92             ROUND(SUM(Nuclear_Electric_Power_Production),2) AS Nuclear_Power,
93             ROUND(SUM(Total_Renewable_Energy_Production),2) AS Renewable_Energy
94      FROM production
95      GROUP BY YEAR(Date);
```

Result Grid | Filter Rows: | Export: | Wrap Cell Content:

Year	Fossil_Fuels	Nuclear_Power	Renewable_Energy
1973	58.21	0.91	4.41
1974	56.29	1.27	4.74
1975	54.7	1.9	4.69
1976	54.68	2.11	4.73
1977	55.06	2.7	4.21
1978	55.03	3.02	5.01
1979	57.95	2.78	5.12
1980	58.98	2.74	5.43

8. What is the Average Primary Energy Production & Consumption?

```
60      -- Average Primary Energy Production & Consumption
61  •   SELECT
62             ROUND(AVG(Total_Primary_Energy_Production),2) AS Average_Energy_Production,
63             ROUND(AVG(Total_Primary_Energy_Consumption),2) AS Average_Energy_Consumption
64      FROM world_energy_overview;
65
```

Result Grid | Filter Rows: | Export: | Wrap Cell Content:

Average_Energy_Production	Average_Energy_Consumption
6.15	7.44

The **Average** Primary Energy **Production** is **6.15 TWh** and the **Average** Primary Energy **Consumption** is **7.44 TWh.**

9. What is the Average Ratio of Production to Consumption?

The average ratio of production to consumption is a measure that compares the amount of energy produced to the amount of energy consumed over a given period (e.g., a year).

```sql
-- Average Ratio of Production to Consumption
SELECT
    YEAR(Date) AS Year,
    ROUND(AVG(Total_Primary_Energy_Production / Total_Primary_Energy_Consumption),2) AS avg_production_to_consumption_ratio
FROM world_energy_overview
GROUP BY YEAR(Date)
ORDER BY avg_production_to_consumption_ratio DESC;
```

Result Grid | Filter Rows: | Export: | Wrap Cell Content:

Year	avg_production_to_consumption_ratio
2020	1.03
2022	1.03
2021	1.01
2019	1.01
2018	0.95
1982	0.92
2015	0.91
2017	0.9
1984	0.9
2014	0.9
1985	0.89
1981	0.88

If the ratio >1 then:

- **Production exceeds consumption**: When the ratio is greater than 1, it means that the total energy produced is greater than the total energy consumed. This can indicate a **surplus** of energy production, where the energy supply exceeds demand.
- **Potential Export or Storage**: In many cases, a ratio greater than 1 suggests that the country or region may be able to **export** excess energy to other regions or **store** it for future use (e.g., battery storage, pumped hydro storage, etc.).
- **Energy Efficiency**: A high ratio may also indicate that energy efficiency improvements in consumption have outpaced the growth in consumption.

If the ratio = 1 then:

- **Balanced production and consumption**: A ratio of exactly 1 means that the amount of energy produced is equal to the amount of energy consumed. There is no surplus or deficit of energy. The system is **balanced**.
- **Self-sufficiency**: This scenario could indicate a **self-sufficient** energy system where the energy needs are fully met by domestic production, with no need for imports or exports.

If the ratio < 1 then:

- **Consumption exceeds production**: When the ratio is less than 1, it means that the total energy consumed is greater than the total energy produced. This indicates an **energy deficit**, where the country or region has to **import** energy to meet its needs.

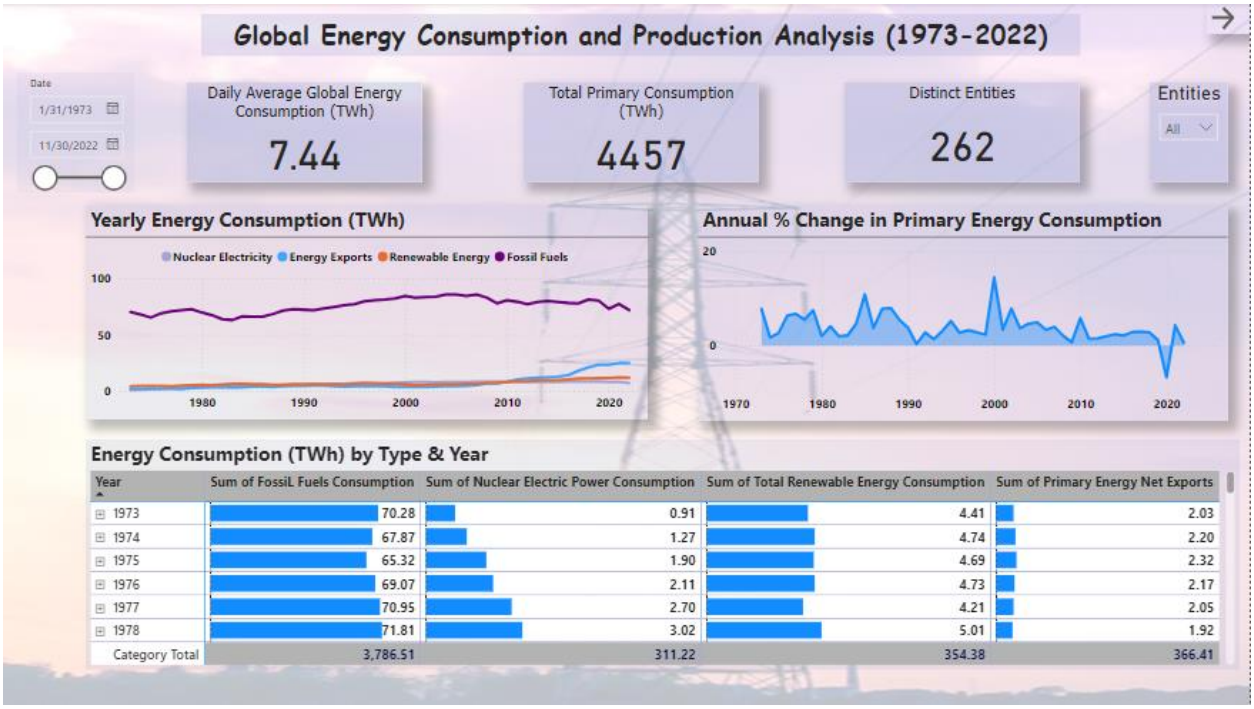
- **Dependence on Imports**: This could imply that the country relies on energy imports, or it may need to purchase energy from external sources to meet its demand.
- **Energy Crisis Risk**: A low ratio (especially if consistently below 1) can be an indicator of a potential **energy security risk** if the country is overly dependent on imports or unable to meet future energy demands with local production.

From our results, it's seen that in **2019**, the **ratio** reached **1.01** and has remained above that level in the subsequent years through **2022.** This indicates that **production exceeds consumption**, there is **potential for export or storage**, or **energy efficiency has improved**.

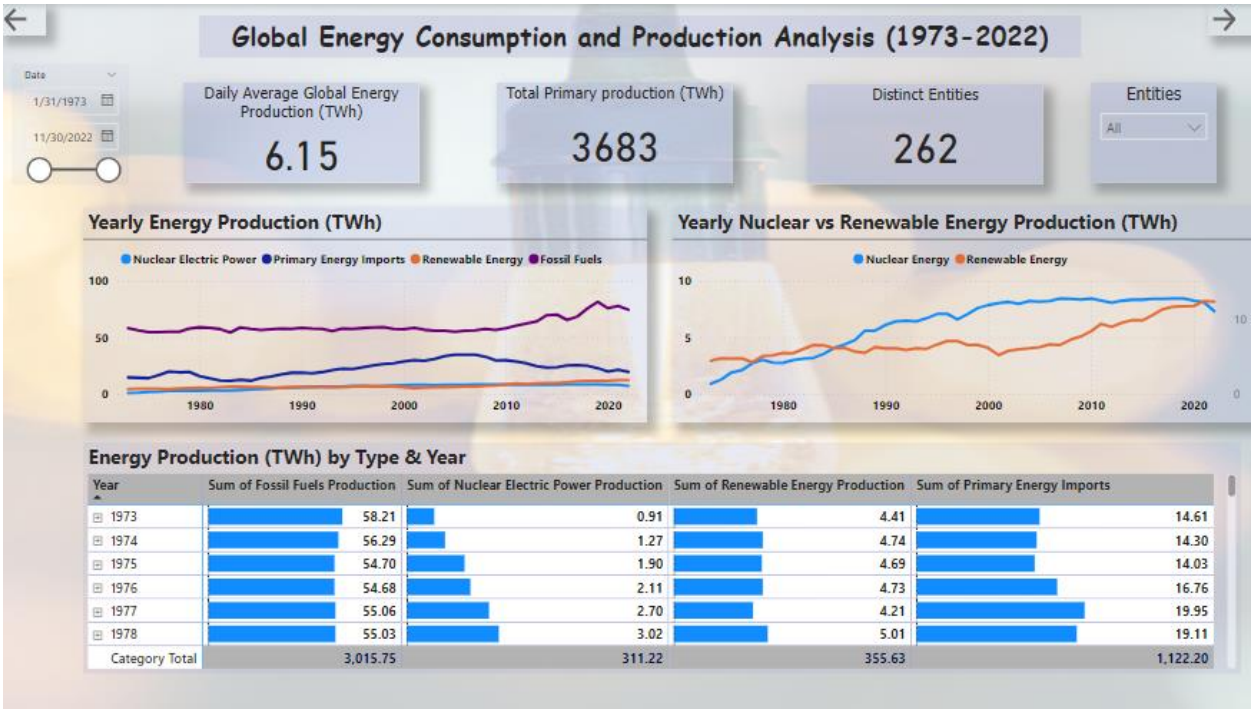
In all the **years prior** to **2019**, the **ratio** was **less than 1**. This indicates that **consumption exceeded production**, there was **dependence on imports**, and there was a **risk of an energy crisis**.

DATA VISUALIZATION USING POWER BI

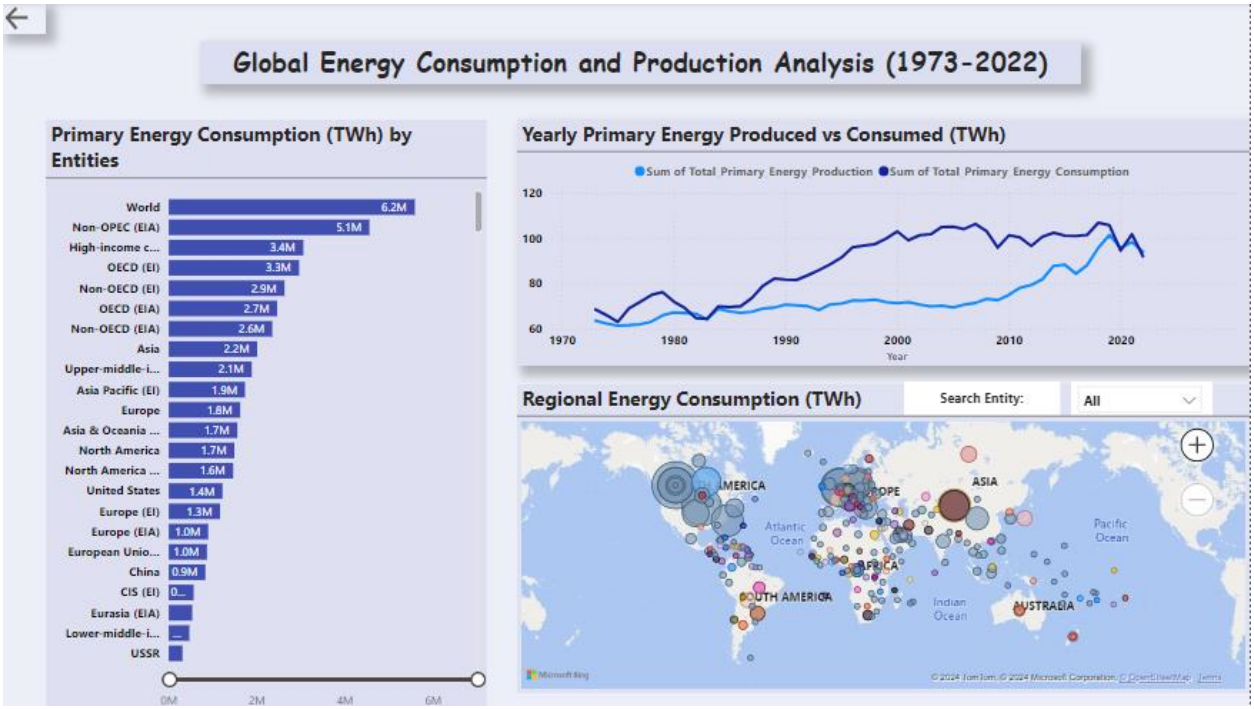
CONSUMPTION DASHBOARD



PRODUCTION DASHBOARD



GLOBAL ENERGY OVERVIEW



FINDINGS

- **Fossil Fuels**: Fossil fuels remain the most produced and consumed energy type from 1973 to 2022.
- **Peak Energy Production**: The highest total primary energy production occurred in August 2022 (8.81 TWh), while the lowest was in February 1978 (4.31 TWh).
- **Peak Energy Consumption**: The highest total primary energy consumption occurred in January 2018 (9.66 TWh), with the lowest recorded in June 1975 (5.44 TWh).
- **Renewable Energy:** Renewable energy production increased sharply from 6.22 TWh in 2005 to 12.26 TWh by 2022, marking a period of rapid growth and diversification in energy sources.
- **Nuclear Energy:** Nuclear electric power saw its most significant growth between 1973 and 2000, with a +6.95 increase.
- **Renewable Energy and Nuclear Energy** both trended up between 1973 and 2022.
- **Production-Consumption Average Ratio:**

  In **2019**, the **Average Ratio of Production to Consumption ratio** reached **1.01** and has remained above that level in the subsequent years through **2022.** This indicates that during that time **production exceeded consumption** and/or there was **potential for export or storage** and/or **energy efficiency had improved**.

  In all the **years prior** to **2019**, the **ratio** was **less than 1**. This indicates that **consumption exceeded production** and/or there was **dependence on imports** and/or there was a **risk of an energy crisis**.
- **Average Primary Energy Production:** 6.15 TWh
- **Average Primary Energy Consumption:** 7.44 TWh.
- **Total Energy Production** on Last Day of Month (1973-2022): 3683 TWh
- **Total Energy Consumption** on Last Day of Month (1973-2022): 4457 TWh
- **Average Annual % Change in Primary Energy Consumption – Peak and Decline Years:** The highest increase occurred in 2000, with a rise of about 14.41% in primary energy consumption. The largest decrease was in 2020, when consumption dropped by approximately 6.77%, likely due to the COVID-19 pandemic's significant impact on global energy demand. Overall, the trend suggests a gradual stabilization over time, likely due to improved energy efficiency and shifts toward diverse energy sources.

RECOMMENDATIONS

1. Transition to Renewable Energy and Diversification

Given the sharp increase in Renewable Energy production since 2005, particularly with the steepest incline between 2005 and 2022, it is crucial to continue investing in and promoting the

adoption of renewable energy sources such as **solar**, **wind**, and **hydropower**. This will help reduce dependence on fossil fuels, which remain the dominant source of energy production and consumption.

2. Focus on Energy Efficiency and Technological Innovations

The trend observed in 2019, where the **Ratio of Production to Consumption** exceeded 1 (1.01), suggests a positive shift towards greater energy efficiency and possibly storage or export capabilities. This indicates that improving energy efficiency should continue to be a priority for the coming years.

3. Enhance Energy Independence and Reduce Vulnerability to Imports

The periods before 2019, where the production-to-consumption ratio was consistently below 1, indicate periods of **energy dependence on imports** and the **risk of an energy crisis**. In light of this, it is vital to strengthen domestic energy production to ensure energy security and reduce reliance on external sources.

4. Continue Support for Nuclear Energy Development

The long growth period of **Nuclear Electric Power** from 1973 to 2000 (+6.95) indicates its significant contribution to stable energy production. Nuclear energy is a low-carbon, high-output energy source that can complement renewable energy in the energy mix.

5. Monitor and Manage Energy Consumption Trends

With January 2018 marking the highest energy consumption (9.66 TWh) and June 1975 recording the lowest consumption (5.44 TWh), it's clear that managing energy demand will be increasingly important as consumption continues to rise. The average consumption of 7.44 TWh suggests a need for better demand-side management strategies.

6. Investigate Potential Export Markets

Recommendation: Since the production-to-consumption ratio has been above 1 since 2019, suggesting potential for export or storage, there is an opportunity to explore energy exports to neighboring countries or international markets.

7. Address Energy Crisis Risk with Proactive Planning

The historical periods of **energy crisis risk** prior to 2019 underscore the importance of proactive energy planning. Energy crises can lead to economic disruption, so strategic energy reserves, predictive analytics, and comprehensive energy policies are critical.

CONCLUSION

The transition toward greater energy independence, sustainability, and efficiency is crucial for the future of energy production and consumption. By investing in renewable energy, improving energy efficiency, and exploring new technologies like nuclear power and smart grids, we can ensure a reliable and sustainable energy future. Continued efforts to balance energy production with consumption and explore energy export opportunities will be key to strengthening national energy security and mitigating risks related to energy shortages or crises.